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AUTHOR Green, Joanne; And Others
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ABSTRACT

This manual contains Progress Checks and Tests for use in a Solar Heating Systems curriculum (see note). It contains master copies of all Progress Checks and Unit Tests accompanying the curriculum, organized by unit. (The master copies are to be duplicated by each school so that adequate copies are available for student use in a self-paced student program.) Types of materials included are written tests, quizzes, and teacher observation sheets. The materials are keyed to the 22 units (tasks) of the curriculum, organized in four major learning modules. The four major topics covered in the curriculum are (1) understanding solar systems; (2) designing solar systems; (3) installing solar systems; and (4) maintenance of solar systems. (KC)

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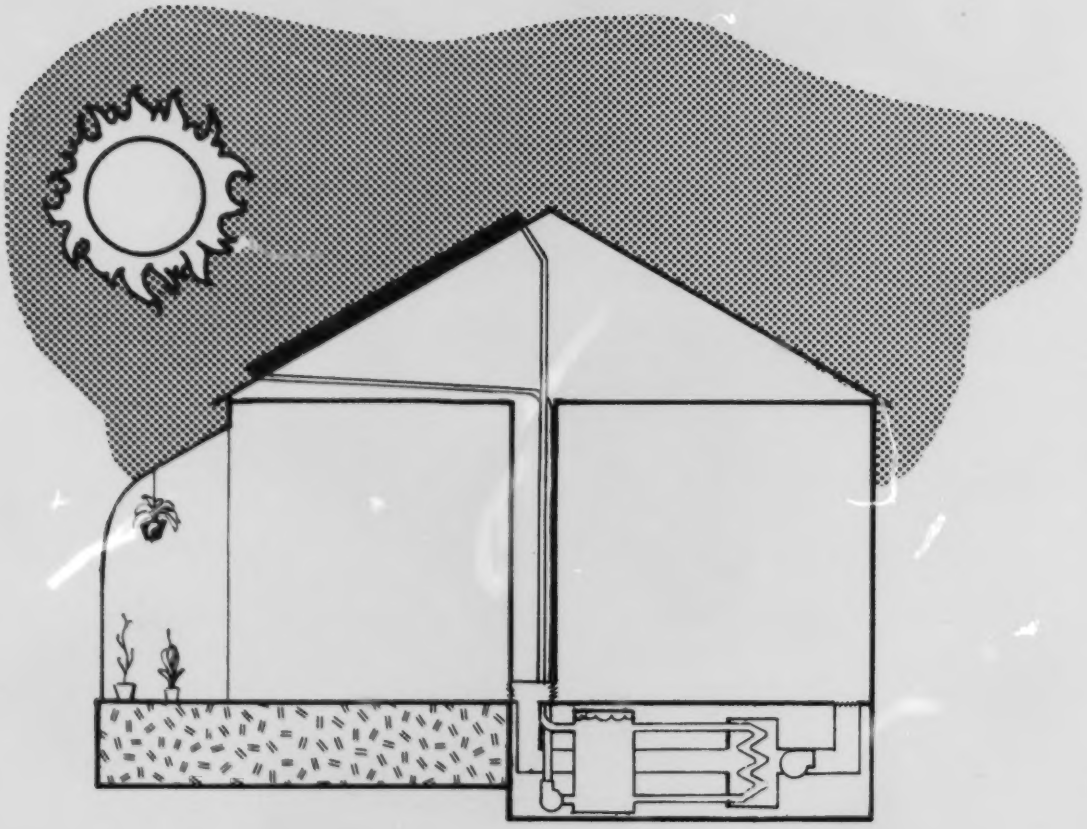
SOLAR HEATING SYSTEMS



PROGRESS CHECKS

&

TESTS MANUAL

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Developed by

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia 30332

Written by:
Joanne Green
Esther Lee Davenport
Joe N. Harris

Graphics designed:
Claude Lattimore

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SOLAR HEATING SYSTEMS CURRICULUM
PROGRESS CHECKS AND TESTS

Each instructor should have copies of three manuals:

1) The Student Manual

2) The Instructor's Guide

3) Progress Checks and Test Manual

The Progress Checks and Tests Manual contains master copies of all Progress Checks and Unit Tests to be used in the Solar Heating Systems Curriculum. These materials are organized by unit, in the order in which they are used. The master copies should be duplicated by each school so that adequate copies are available for student use. Since this is a self-paced curriculum, it is important that copies be readily available when students are prepared to proceed in their work.

UNIT SA-1
PROGRESS CHECK (C-2)
WRITTEN QUIZ

PART A

Match each term with its definition:

_____ a. nonrenewable energy source

_____ b. photovoltaic

_____ c. direct radiation

_____ d. diffuse radiation

_____ e. insolation

_____ f. solar constant

_____ g. renewable energy source

_____ h. Btu

_____ i. pyrheliometer

_____ j. latitude

_____ k. convection

1. Converts solar radiation to electricity.
2. The solar energy which reaches the earth's surface.
3. Will someday be all used up.
4. Used to measure heat energy.
5. Is uninterrupted in its path to the earth.
6. Amount of heat necessary to increase the temperature of one pound of water one degree Fahrenheit.
7. Is of unlimited quantity.
8. Indicates the distance from the sun's equator.
9. The amount of solar energy striking the outer atmosphere which varies only slightly.
10. Is scattered as it travels through the atmosphere.
11. Heat transfer that occurs in fluids because heated fluids are lighter and rise.

PART B

1. At what time of day is solar insolation the greatest?

2. List two points with regard to each of the following topics:

   a. Problems with conventional fuels:

      1.

      2.

   b. Advantages of solar energy:

      1.

      2.

3. Why is the radiation received on earth less than that hitting the outer atmosphere?

4. What have you found most interesting so far in this unit?

1. List two advantages of solar energy systems.
   a.

   b.

2. Two examples of nonrenewable resources are _____ and _____.
3. A _____ is a device which converts solar energy to electricity.
4. What is the value of the solar constant? _____
5. The instrument used to measure solar insolation is called a _____.
6. The kind of radiation which produces maximal heat energy is called _____ radiation.
7. _____ $Btu/ft^2/hr$ are received on earth at noon on a sunny day.
8. When heat energy travels from one area to another as the heated fluids rise, this is known as _____.
9. Identify each of the following as examples of conduction, convection, or radiation:
   _____ a. The street becomes hot on a sunny day.
   _____ b. If we hold a marble in our hand, it becomes warm.
10. The maximal insolation during a day is received at _____.

11. In the northern hemisphere, solar collectors should be oriented so they face _____.

12. The north walls of a building in the northern hemisphere receive _____ radiation, but not _____ radiation.

13. What is a British thermal unit?

14. Define insolation.

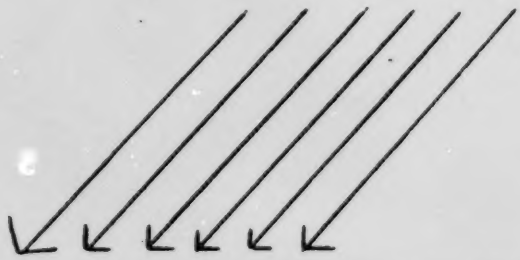
15. Why is less radiation received on earth than that hitting the earth's outer atmosphere?

16. For a location at a 30° latitude, what collector tilt angle would you recommend for:
    a. space heating only _____
    b. heating domestic hot water only _____

10

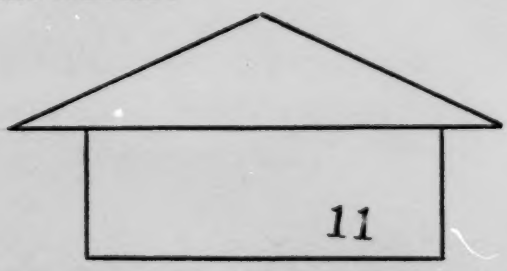
17. Using Information Sheet A-1-1, calculate the solar time at 4 P.M. in January for a location which is in the Eastern Time Zone, and which has a longitude of 70°.

18. In the drawing below, illustrate how you would tilt a surface to capture maximal solar radiation.



19. Why does the tilt angle appropriate for maximal insolation vary with the season?

20. In the diagram below, show how the overhang affects the path of the sun's rays to shade the house in the summer, but not in the winter.

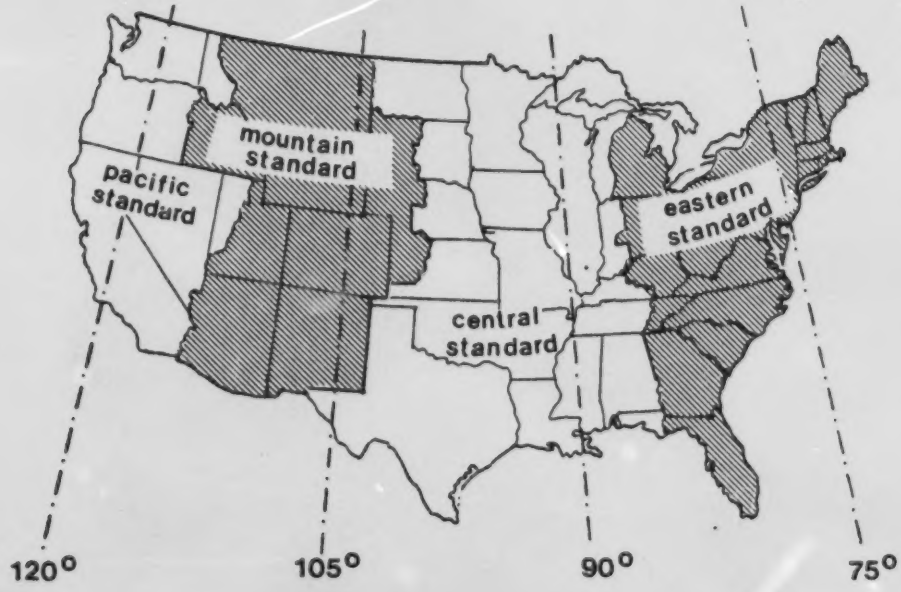


21. Why do you think that people are reluctant to install solar energy systems in their homes?

SOLAR TIME VERSUS CLOCK TIME

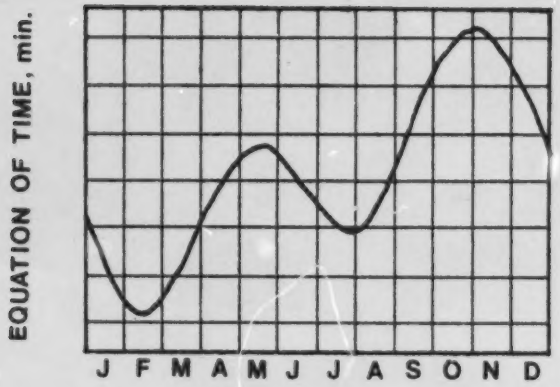
Most of us are accustomed to telling time by use of a clock. In solar system design, however, it is important to recognize that clock time does not necessarily indicate solar time. Solar noon for a given location is the time when the sun is most directly overhead. Solar noon is the time when there is the greatest solar radiation reaching surfaces on earth. Solar noon does not always occur when it is noon according to the clock. Solar noon is closest to clock time noon for locations whose longitude is at the middle of their time zone (the "meridian").

Figure 1 indicates the meridian of each of the time zones in the continental United States.



For locations which are either east or west of their time zone meridian, solar time is slightly different from clock time.

Solar time also differs from clock time because in its daily revolution the earth does not revolve at a constant rate. Figure 2 indicates the amount of time which must be subtracted or added to clock time to correct for variations in the earth's revolution. As can be seen, the correction factor varies from month to month, ranging from zero to sixteen minutes.



In designing a solar system, it is important to be able to determine the solar time from clock time. This is particularly important because solar insolation is greatest at true solar noon, rather than at noon according to clock time.

To determine the solar time from clock time for your area, the following steps can be followed:

1) Correction for Daylight Savings Time: If daylight savings time is in effect, subtract one hour from clock time.

2) Correction for local location: Determine the longitude of your locality and the longitude of the standard time meridian (75^{o} for E.S.T, 90^{o} for C.S.T, 105^{o} for M.S.T, and 120^{o} for P.S.T). Multiply the difference between the two by 4 minutes/degree. If your locality is east of the standard meridian, add this correction factor to clock time. If you are west of the standard meridian, subtract this correction factor.

3) Correction for variation in earth's rate of revolution: For each month of the year, Figure 2 indicates the amount of time which should be added or subtracted from clock time.

UNIT SA-2
PROGRESS CHECK (C-1)
WRITTEN QUIZ

Make a schematic drawing of the major components of a solar space heating system. Indicate the direction in which heat flows when there is space heating from the storage tank.

1. Draw a schematic diagram of the major components of a solar system designed for solar space heating. Label each component. Indicate the direction of heat flow when the storage unit is being heated.

2. Fill in the blanks.

   a. A device called a _____ is used when heat must be transferred from one fluid to another.

   b. In solar heating systems, the unreliability of solar energy makes necessary the inclusion of the following components: _____ and _____.

   c. The kind of collector most frequently used in residential systems is the _____.

   d. A _____ solar system uses mechanical means in transporting heat for storage or distribution.

   e. The _____ is the component of the collector which converts solar radiation to heat.

   f. Solar systems which use air to transfer heat from the collector are known as _____ systems.

   g. The back-up component of a solar space heating system is the _____.

   h. A _____ storage unit may be used to store "cold" at night for use during the day.

   i. A _____ is a refrigerant machine that can extract heat from a source that is at a temperature too low for direct comfort applications.

   j. A _____ collector collects both direct and diffuse solar radiation.

3. Label each of the following statements as true (T) or false (F).

   a. _____ Roof overhangs illustrate use of active solar systems design.

   b. _____ The transparent plate in a collector prevents heat loss by convection.

   c. _____ Liquid storage is usually used in air systems.

   d. _____ Usually one collector can satisfy residential heating requirements.

   e. _____ Pumps are frequently used in passive systems.

f. _____ Solar space heating systems cannot be built without including a solar water heating system.

g. _____ Fluid returning to the solar collector is usually cooler than fluid leaving the collector.

h. _____ Leaks are less damaging in air systems than in water systems.

i. _____ Air systems use less energy in transporting heat from collector to storage than do liquid systems.

j. _____ Heat pumps can be incorporated in solar heating systems or in solar cooling systems.

k. _____ Solar heat can be used to drive the condenser in absorption cooling systems.

l. _____ A roof pond which is used for cooling in the summer should be covered at night.

4. List 3 advantages and 3 disadvantages of air systems and of liquid systems. Use the table below to outline your answer.

AIR

Advantages	Disadvantages
1.	1.
2.	2.
3.	3.

LIQUID

Advantages	Disadvantages
1.	1.
2.	2.
3.	3.

1. What is air infiltration?

2. Name four ways to reduce air infiltration.

3. R-value measures resistance to _____.

4. The reason 2" x 6" studs are used in the Arkansas Plan home is:

5. What is the difference between weatherstripping and caulking?

6. If a material has an R-value of 3, per inch of thickness, how many inches of the material are needed to give an R-value of 18?

7. What R-value should walls and ceilings in your area have?

8. Should interior walls and ceilings under heated spaces be insulated?

9. What side should a vapor barrier face?

10. Describe ideal placement of windows from an energy efficiency standpoint.

INSTRUCTOR OBSERVATION

Review the student's written work for each of the Job Sheets and Assignment Sheets in this unit. Check that the student has corrected his answers on the written quiz. Other written work should be corrected in such a way that it can be a useful reference for the student in the future.

When you are satisfied that his work is thorough and of high quality, allow him to move on to the Unit Test (written portion). When his score on the test is at least 25 out of 30 points, the student should be ready to undertake Job Sheet SB-1-3. See your "Instructor's Materials" for your responsibilities for this activity.

1. Air leakage in a house is called _____.

2. Name four locations for air leakage in most houses.

3. Name remedies for leaks at these locations.

4. What type framing does Arkansas Plan construction use?

5. Why does Arkansas Plan framing help energy efficiency?

6. There is less lumber used in Arkansas Plan construction. True or False?

7. Plywood headers over windows and doors are required for structural strength in Arkansas Plan Houses. True or False?

8. It is not recommended that concrete slab floors be insulated. True or False?

9. Duct work should be placed, wherever possible, within insulated living space. True or False?

10. Caulking and weatherstripping act to: (Circle one.)

    a) Increase the R-value of walls
    b) Reduce air exchange
    c) Keep out insects
    d) Reduce energy use
    e) All of the above.

11. Weatherstripping is used where: (Circle one.)

    a) Doors and windows open and close
    b) Cracks exist around door frames
    c) Soffit vents
    d) Caulking is too noticeable.

12. Most brands of weatherstripping are pretty much the same, in terms of durability, cost, and ease of installation. True or False?

13. Most brands of caulking are the same, in terms of durability. True or False?

14. Weatherstripping and caulking should be done: (Circle one.)

    a) After all other energy-saving measures are complete
    b) Frequently
    c) As an essential first step.

15. Name three types of caulking and report their advantages, disadvantages, and cost.

16. Name three types of weatherstripping and report their advantages, disadvantages, and cost.

17. R-value is resistance to _____.

18. Cellulose fiber is a naturally fire-resistant insulation. True or False?

19. Name two problems with urea formaldehyde insulation.

20. The highest R-value per inch is given by _____.

21. R-values recommended for your area for the following locations are:

    a) Ceilings under unheated space _____

    b) Exterior walls _____

    c) Floors over unheated space _____

22. What is the purpose of a vapor barrier?

23. Are all vapor barriers fire-resistant?

    Which side should the vapor barrier face?

24. The air space between studs in an uninsulated wall has an insulating value that is:

    a) higher than,
    b) lower than,
    c) about equal to,

    insulating sheathing.

25. Here is an example of an $R\text{-value}_{TOTAL}$ calculation. Check each step for correctness.

    Example: The wall is made of:

1" exterior siding	R-value of .8, per inch
½" insulating sheathing	R-value of 1.0, per inch
3½" air space	R-value of .33, per inch
½" gypsum wallboard	R-value of 1.0, per inch

    Calculation: The R_{TOTAL} for the wall is figured in five steps.

Step One.	1" x .8 = .8	Correct? _____
Step Two.	½" x 1.0 = .5	Correct? _____
Step Three.	3½" x .33 = .99	Correct? _____
Step Four.	1" x 1.0 = 1.0	Correct? _____
Step Five.	Add up all the R-values to get R_{TOTAL} for the wall.	Correct? _____

26. High gloss enamel can be a good vapor barrier. True or False?

27. The best orientation for windows is _____.

28. Explain why you answered #27 as you did.

29. a) Jalousie, crank-type windows are better than casement windows for energy efficiency. True or False?

    b) Wood windows are more energy efficient than metal windows. True or False?

30. From what you have studied so far in the course on solar energy, why should a solar heating technician expert know about energy efficiency?

CONDUCTING BUILDING ENERGY EFFICIENCY AUDIT

MATERIALS:

Energy Survey Form (See Procedures)
Audit Site: The dwelling of an individual selected with the assistance of your instructor. This may be your own, a friend's, or a site chosen by your instructor.
Cassette Tape Recorder and Cassette Tape

PROCEDURE:

Based on the reading you have done in this unit, make up a checklist of features you think an energy efficient house should have. This checklist will be used by you in conducting the Energy Efficiency Audit. Your local power company's energy assistance office may be of assistance to you here, since they provide this service free to homeowners.

Submit the form you create to your instructor for approval.

With the aid of your instructor, make an appointment with the occupants of the audit site to do an energy efficiency audit for this individual.

After completing the Survey form, write down a set of recommendations for making the dwelling visited more energy efficient, along with the approximate costs in your area for making these changes.

Review your recommendations and cost estimates with your instructor. Make a second appointment with the resident of the dwelling you audited, for the purpose of going over the recommendations with him or her. Request permission from the resident to tape record your presentation to him. Make the presentation at the time you've arranged, and tape record the interview for return to your instructor for grading. This entire exercise is 70% of your grade for the unit. Your grade will be dependent on:

(1) The comprehensiveness (covering all unit materials) and accuracy (reflecting unit information) of your Survey.

(2) The clarity with which you present your findings to the "customer." You should not use technical terms unless you explain them to the customer. You should explain why the problems you discover are important.

Review with the student all Assignment Sheet written answers. Use the answers supplied in the "Instructor's Materials" as a guide for your discussion with the student.

Define the following terms:

1. Passive solar system.

2. Hybrid solar system.

3. Direct gain.

4. Indirect gain.

5. Isolated gain.

6. Name two examples of Indirect Gain systems.

7. Name two examples of Isolated Gain systems.

8. Name one way to avoid wide temperature swings in a Direct Gain heating system.

9. Single glazing on a south wall in Atlanta provides a net energy gain of _____Btu/ft^2/hr.

10. Double glazing on a south wall in Atlanta provides a net gain of _____Btu/ft^2/hr.

11. The best orientation for the long axis of a house is

12. Name several controls for passive heating/cooling systems.

13. In a Mass Trombe Wall, what is the function of the vent at the bottom?

14. In what two ways is heat provided by the Mass Trombe Wall?

15. Name four main aspects of the design of a house that affects the amount of solar energy it receives.

16. Name two ways to affect the amount of heat a house stores.

17. True or False: Most materials which are good heat storage means are rather poor insulation.

18. True or False: For each degree Fahrenheit rise in temperature, a cubic foot of water stores more heat than a cubic foot of concrete.

19. During the summer, a building will normally gain the most heat on its _____walls.

    During the winter on its _____walls.

20. To take advantage of the heat provided by south facing windows, about how much heat capacity should be provided for storage for each square foot of window area:

    (a) When the mass is exposed to the sun.

    (b) When the mass is not exposed directly to the sun.

1. A heating system for a house in which the principal energy flows are due to natural convection and radiation is called _____

A system in which some of the energy flows are by natural convection and radiation and some are forced is called a _____ system.

3. The primary elements in a passive solar system are:

True or False:

4. Single glazing on a south wall provides a net heat gain anywhere in the U. S. _____

Use of passive solar principles means that more than 50 percent of heating needs can be provided by the sun. _____

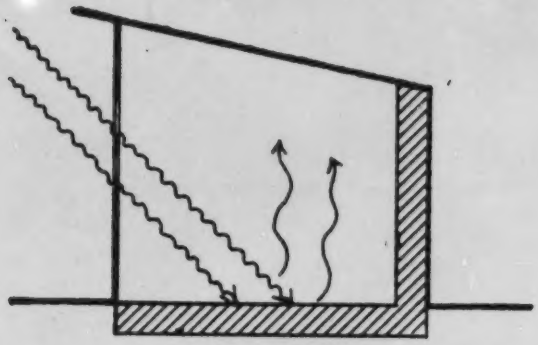
Good insulation is also good thermal mass. _____

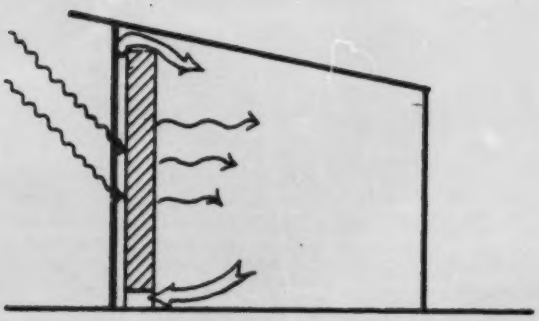
5. If a house has 100 square feet of south-facing window, how much thermal capacity should be available:

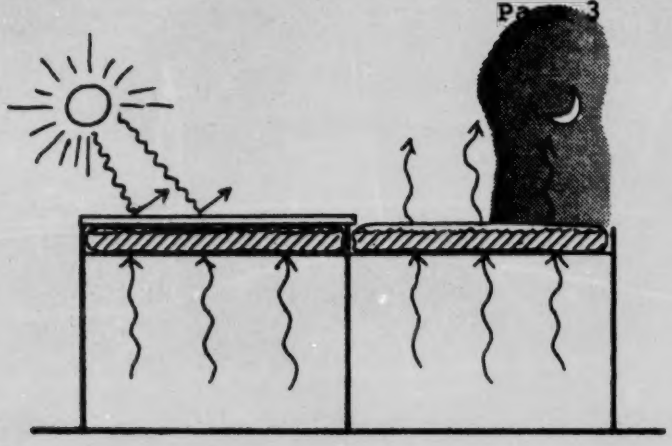
   (a) exposed to the sun

   (b) not exposed to the sun

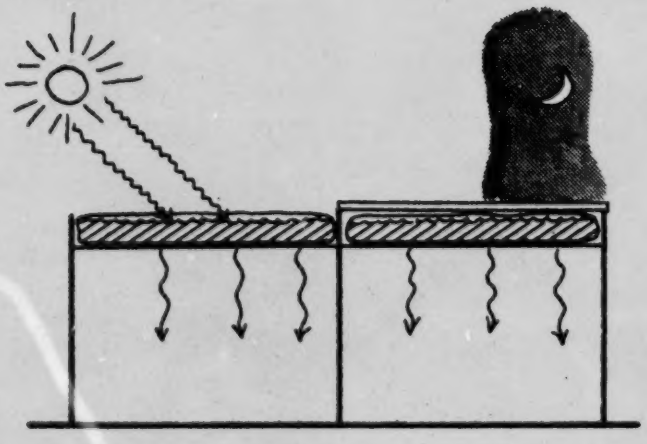
6. The diagrams below show six major passive design types. Name each.



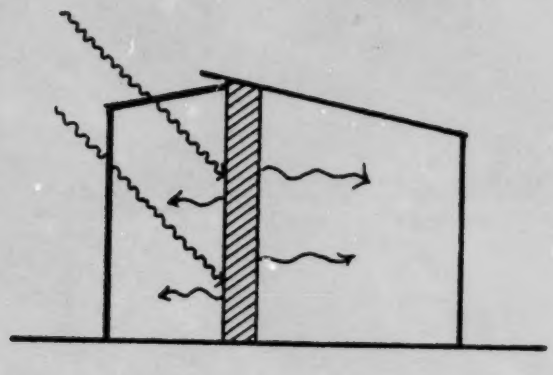


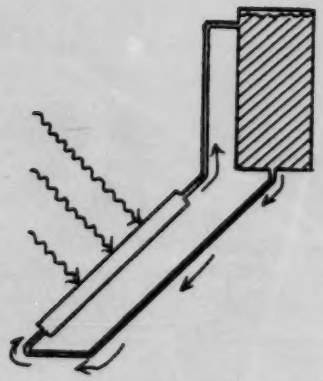


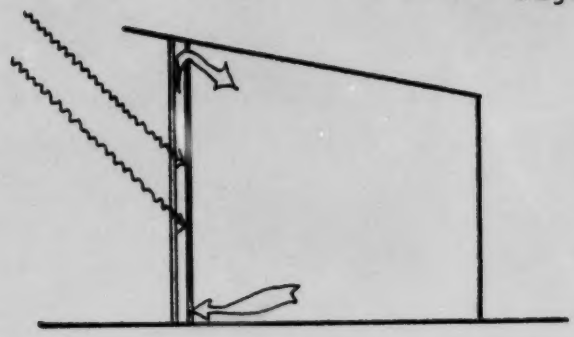
Summer Cooling



Winter Heating







35

13. Suppose you have a Trombe Wall used for winter heating. What can you do to prevent overheating in the summer?

14. How does a roof pond work for heating and cooling?

15. Name three common building materials which are effective as heat storage materials.

Rank order the three you named with respect to their heat capacities:

Is water better or worse than the best above?

16. Which of these is most economical for use in your area, considering material and labor costs?

17. Name three commonly used controls for passive systems.

18. Define: convective loop/thermosiphon:

19. Name principle disadvantages to use of passive solar heating/ cooling in your area.

20. Name principle advantages to use of passive solar heating/ cooling in your areas.

UNIT SB-3
PROGRESS CHECK (C-1)
(peer quiz)

Questions to be asked, and answered orally are:

From Assignment Sheet SB-3-2: questions a, b, f

From Assignment Sheet SB-3-5: questions a, d, h

The student passes the progress check if s/he answers correctly four out of six questions.

UNIT SB-3
PROGRESS CHECK (C-3)
(teacher oral quiz)

Questions to be asked, and answered orally are:

Assignment Sheet SB-3-7: questions b, c

Assignment Sheet SB-3-8: questions b, c, j, k

The student passes the progress check if s/he answers correctly four out of the six questions.

1. Circle T or F to indicate whether each of the following statements is true (T) or false (F).

   a. T F Flat plate collectors can be placed on any part of the roof, and still operate effectively.

   b. T F Concentrating collectors pivot during the day.

   c. T F Most radiation that strikes a collector is absorbed by the cover plate.

   d. T F The average annual temperature helps determine the number of cover plates necessary on a collector.

   e. T F Liquid collectors are larger than air collectors because of the space needed for piping.

   f. T F A black absorber plate should absorb about 90% of the radiant energy.

   g. T F Fluid should travel upward in a liquid collector.

   h. T F A selective absorber surface increases reradiation of infrared energy from the absorber plate.

   i. T F Concentrating collectors are referred to as low temperature collectors.

   j. T F Flat plate collectors absorb direct and diffuse radiation.

   k. T F The inner surface of the cover plate of a collector should transmit long wave radiation.

   l. T F Flat plate collector temperatures usually achieve a maximum of about 150° F.

   m. T F A closed collector loop requires smaller pumps than an open collector loop.

   n. T F Corrosion is more of a problem in an open loop system.

2. a) Two problems that may occur in liquid, but not air systems are _____ and _____.

   b) The basic parts of a solar collector are:

   1. _____ 4. _____

   2. _____ 5. _____

   3. _____

c) The heating within a collector, and the heating of the inside of a car by solar radiation are both examples of the _____ effect.

d) To increase transmittance of heat from the absorber plate to the air, air collectors usually include _____.

e) Two advantages of liquid systems, as compared to air systems are:

a.

b.

f) A flat plate solar collector captures the most heat energy during the day at _____.

g) A _____ collector loop is one in which the liquid is not exposed to air.

h) A _____ is used to strain particles out of the liquid in a collector loop.

i) Two cover plates are generally used in flat plate collectors if the annual temperature averages below _____.

j) When ethylene glycol is used as both an antifreeze and corrosion inhibitor, its minimum concentration should be _____.

UNIT SB-4
PROGRESS CHECK (C-1)
(written quiz)

a. The specific heat of water is _____.

b. Rock has a (lower, higher) specific heat than does water.

c. Storage systems which involve materials that change from solid to liquid during heat storage are known as _____ storage systems.

d. Heat absorbing materials that change from solids to liquids are (more, less) expensive than sensible storage materials.

e. To absorb a given amount of heat, a (rock, water) storage unit would have to be larger.

f. How many Btu's are absorbed by a 150 ft^3 rock storage unit during a temperature change from 110° to 140° F? Apply the formula listed below.

Number of Btu's absorbed =

$$\text{Volume of Storage Unit } (ft^3) \times 100\ lb/ft^3 \times .20\ Btu/lb \times (\text{final-initial temperature})$$

UNIT SB-4
PROGRESS CHECK (C-4)
(peer quiz)

The following questions should be answered orally:

Assignment Sheet SB-4-9: Question a

Assignment Sheet SB-4-11: Questions a, b, c, g

The student passes the Progress check if s/he answers correctly three out of five questions.

1) Indicate whether each statement is true or false by circling T (true) or F (false). (3 1/3 points each.)

a. T F Rock storage usually takes up less space than liquid storage.

b. T F Rock has a lower specific heat than water.

c. T F To retain a comparable amount of heat energy, wax requires a larger heat storage tank than water.

d. T F Phase change storage systems are not presently used as often as sensible heat storage systems.

e. T F The first consideration in locating a storage unit is that it be very close the collectors.

f. T F If a storage unit is too small for a system, overheating may occur.

g. T F Heat storage system sizes are determined by the average daily temperature in January.

h. T F An advantage to concrete storage tanks is that watertight connections are easy to make.

i. T F One problem with locating storage units below grade is that they may be difficult to access for repair.

j. T F Galvanized steel storage units suffer the disadvantage that they may corrode over time.

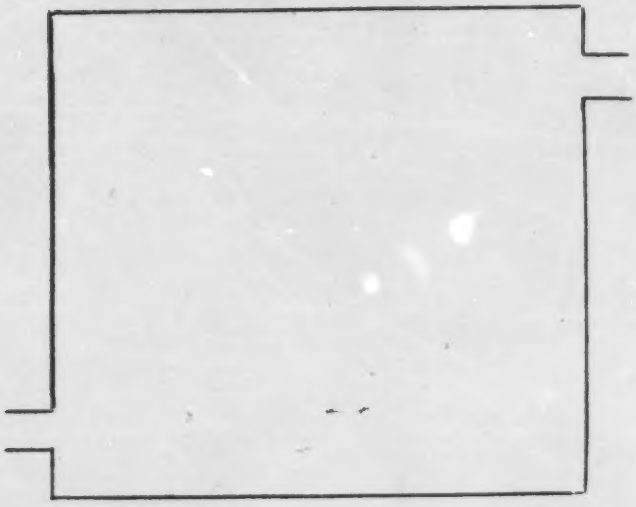
k. T F Cubic pebble beds are preferred over horizontal pebble beds.

l. T F A moderately priced storage tank can be designed so that the solar system can satisfy 90% of the space heating demand.

2) In the diagram below, indicate with arrows the direction of fluid flow

a. during heat storage (3 1/3 points)

b. during heat distribution to spaces (3 1/3 points)



3) Fill in the blanks with the correct response. (3 1/3 points each correct answer.)

a. The ability of a material to absorb heat is described numerically by its _____ _____.

b. A storage system in which a material changes from a solid to a liquid as it absorbs heat is known as a _____ _____ storage system.

c. The size of the storage unit depends on two factors: the _____ and the _____.

d. In storage units, there are differences in the amount of heat stored in different layers of the storage material, with the most heat being stored in top layers. This is known as _____ _____.

e. In a water storage unit, the minimum temperature useful for space heating is about _____.

f. Two practical locations for a storage unit in a house are in _____ or in _____.

g. One problem with water storage units, but not rock storage units is _____. However, rock storage units have the disadvantage that they _____ _____.

4) How many Btu's are absorbed by a 1000 gallon water storage unit in a temperature change from 150° F to 180° F? (3 1/3 points)

Number of Btu's absorbed =

$$\text{Volume of Storage Unit} \times 8.34 \text{ lb/ga} \times 1 \text{ Btu/lb} \times (\text{final-initial temperature})$$

5) If a collector array is 500 square feet, what is the largest water storage tank that should be used? (3 1/3 points)

6) List two possible problems with water storage units, and indicate a method for minimizing each problem. (3 1/3 points each correct answer)

UNIT SB-5
PROGRESS CHECK (C-1)
PEER QUIZ

The student should be asked the following questions:

Assignment Sheet SB-5-2: Questions b, c, f, h, k

Assignment Sheet SB-5-4: Questions b, e, g, j, k

The student passes the Progress Check if s/he answers correctly seven or more questions.

UNIT SB-5
PROGRESS CHECK (C-3)
INSTRUCTOR ORAL QUIZ

1) The instructor will show the student five control devices. S/he is to name the device, function, and where it might be located in a solar system.

2) The student should also answer orally the following questions:

Assignment SB-5-5: Questions a, e, f, k

Assignment SB-5-7: Questions b, g, i, j

UNIT SB-5
PROGRESS CHECK (C-5)
INSTRUCTOR ORAL QUIZ

The instructor will show the student five hydronic specialty devices, preferably in an installed solar system. S/he is to name the devices, their functions, and where they might be located if they are not in an installed system.

UNIT TEST (SB-5)

1. Circle T or F to indicate whether each of the following statements is true (T) or false (F). (3 1/3 points each.)

   a. T F Larger pumps are required in open loop systems as compared to closed loop systems of comparable size.

   b. T F One-speed pumps are as effective as two-speed pumps.

   c. T F Static pressure is the type of pressure measured in automobile tires.

   d. T F In low pressure systems, velocity pressure is most often used as a design standard for moving air.

   e. T F A differential thermostat measures the temperature in one place.

   f. T F A thermistor operates as a function of the difference in expansion of two metals.

   g. T F Corrosion affects the sensitivity of a thermistor.

   h. T F Liquid collector loops must be filled manually.

   i. T F As static pressure increases, pump capacity decreases.

   j. T F Solar control devices operate at a lower voltage than other hardware appliances.

2. Fill in the most correct answer. (3 1/3 points each correct answer.

   a. Pump capacity is given in _____ per _____.

   b. The most common type of heat exchanger used between collector and storage is called the _____ heat exchanger.

   c. Three types of pressures that apply to air movement are _____, _____, and _____ pressure.

   d. An air system should operate at the point where the _____ and _____ curves intersect.

   e. The point at which an air system should operate is called the _____ point.

f. The first stage of a two-stage thermostat calls for heat from the _____.

g. To reduce corrosion among dissimilar metal piping and components, they are connected by _____ unions.

h. The kind of pump most widely used in solar systems is the _____ pump.

i. Pumps in open loops should be made of _____ to minimize corrosion.

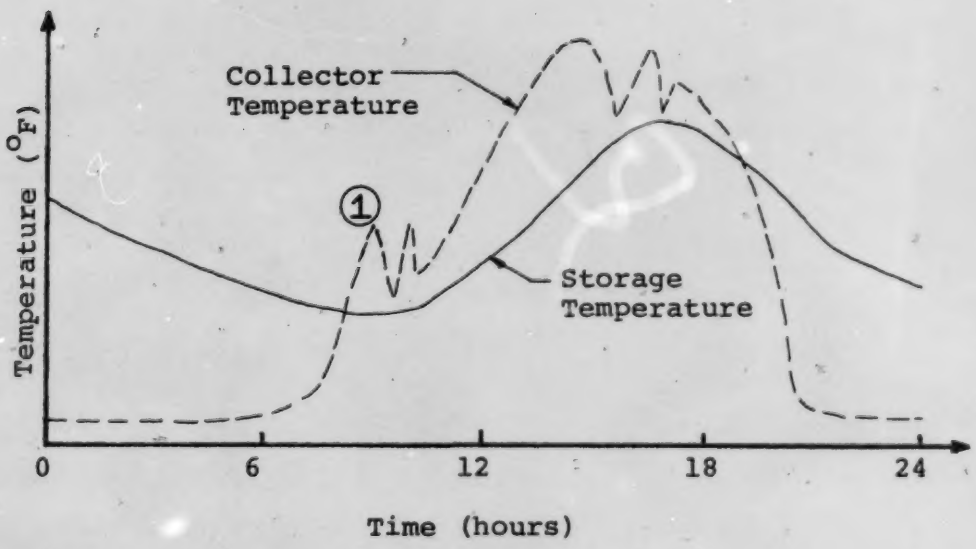
j. In a space heating system, temperatures sensors are installed in three locations: _____, _____, and _____.

k. A temperature difference of about _____ degrees Fahrenheit usually turns on the collector/storage pumps.

l. A _____ valve limits fluid flow to one direction.

m. A _____ _____ valve prevents excessive pressure build-up.

3. Describe what happened in the control system at Point 1, indicated below. (6 2/3 points.)



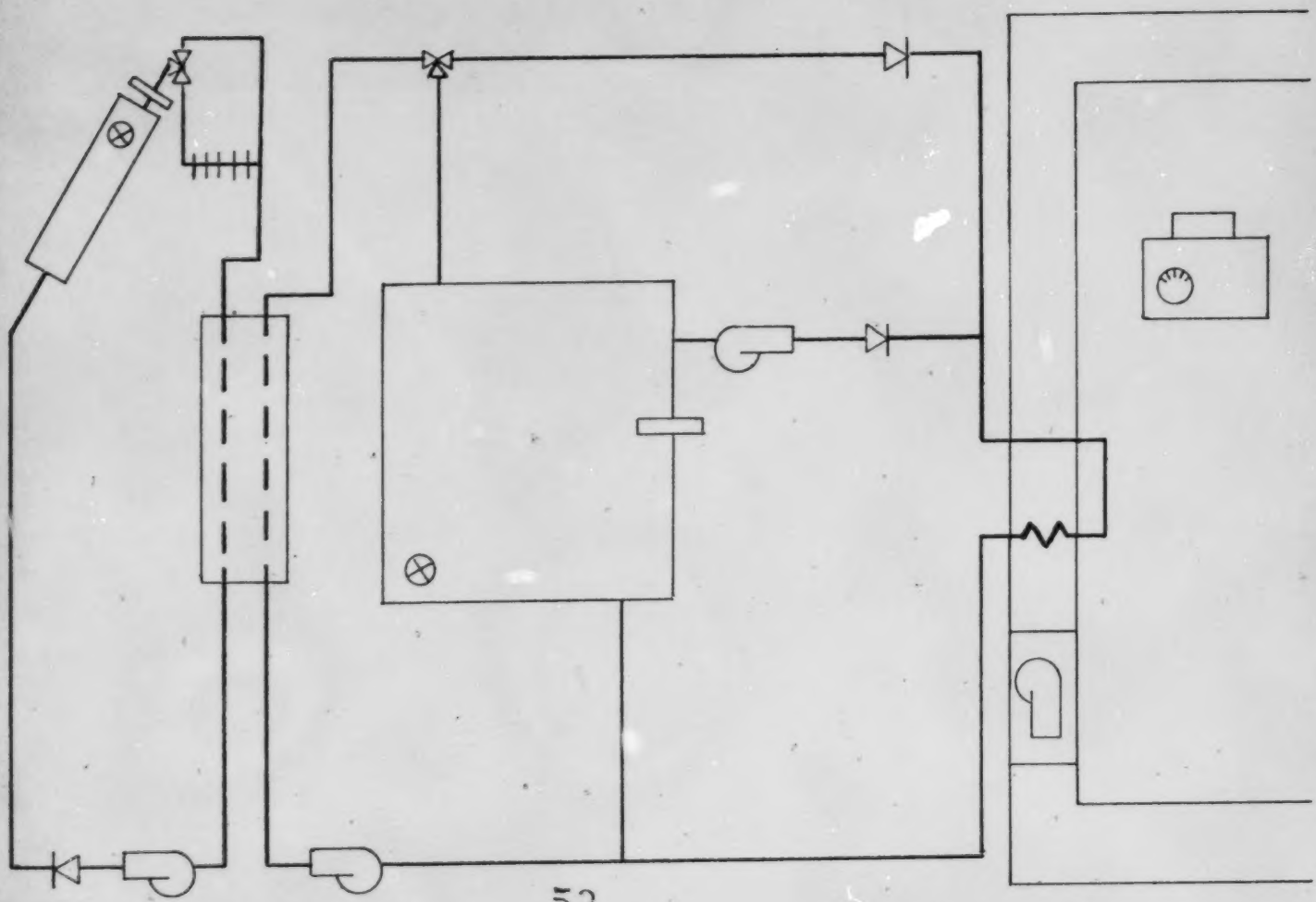
UNIT SB-6
UNIT TEST

1) Use one copy of the provided diagram to illustrate space heating from collectors.

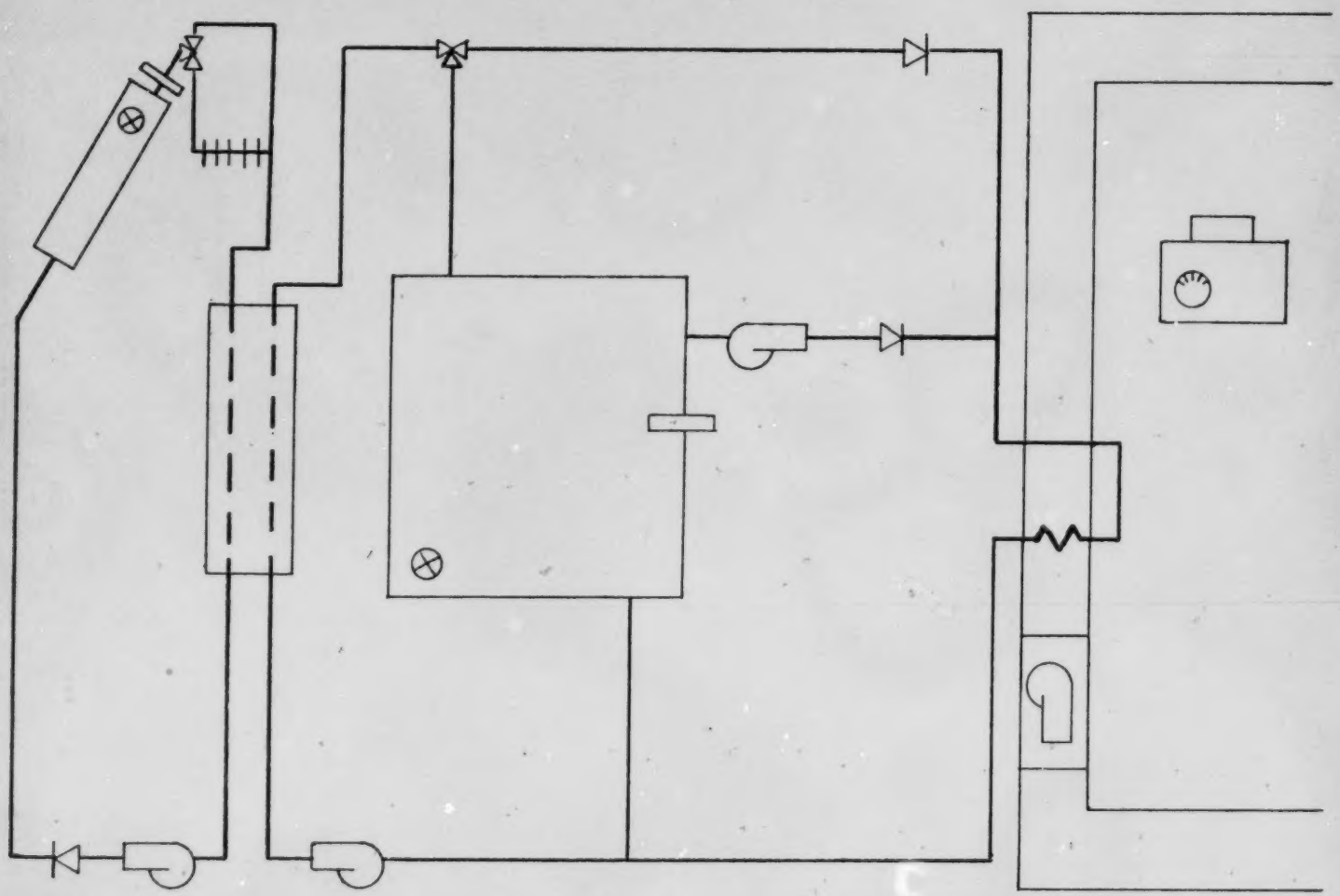
2) Label all parts of the liquid solar system illustrated in Diagram 1. Then, indicate which parts are involved, and how they function in heating from collectors.

3) Use Diagram 2 to illustrate which parts are involved and how they function in storing heat from the collectors.

Mode of Operation: Heating from Collectors



Mode of Operation: Storing heat



UNIT SB-7
PROGRESS CHECK (C-1)
Self-graded quiz

1) Calculate U for the wall with layers indicated below:

	R
Outside air film (winter)	.17
Face brick (4-inch)	.44
Common brick (4-inch)	.44
Air space (3/4-inch, non-reflective)	1.28
Gypsum board (½-inch)	.45
Inside surface	.68

2) Calculate R for the following materials:

a. Common brick (3-inch): 1/k = .20

b. Gypsum board (1-inch): 1/k = .90

c. Softwood board (½-inch): 1/k = 1.25

3) The U value of a material describes:

UNIT SB-7
PROGRESS CHECK (C-2)
Written Quiz

1) The small cottage is 15 x 20 feet in floor area, and has a 12 foot ceiling height. The winter design temperature for the area is 25° F, and the indoor design temperature is 65° F. For the walls, U = .07. For the ceiling, U = .05.

a. What is the rate of heat loss through the walls?

b. What is the rate of heat loss through the ceiling?

c. What is the total rate of heat loss?

UNIT SB-7
PROGRESS CHECK (C-3)
WRITTEN QUIZ

A house in Rome, Georgia has a winter heat loss of 52,170 Btu/hr. The winter design temperature for Rome is 16° F.

a. Calculate the space heating load per degree day.

b. Calculate the monthly heat load in February. (DD=577)

57

UNIT SB-7
UNIT TEST

1) Calculate U for the wall described below:

Outside surface
Face brick (4")
Concrete block (2 rectangular cores, 8" sand and gravel aggregate)
Air space (3", non-reflective)
Gypsum board (½ inch)
Inside surface (non-reflective)

2) Based on degree days, circle the colder of the two cities in March.

Athens, Georgia	or	Atlanta, Georgia
Columbus, Georgia	or	Augusta, Georgia
Sioux City, Iowa	or	Pocatello, Idaho

3) A house in Savannah, Georgia has an area of 40 ft by 50 ft, and has 12 ft ceilings.

a. If the coefficient of heat transmission for the walls is .45, what is the winter rate of heat loss through the walls?

b. The house has two solid wood slab doors, each 1.50" thick with no storm door, with each having an area of 7 feet by 4 feet. What is the winter rate of heat loss through the doors?

4. A house in Tampa, Florida has a heat loss rate of 32,000 Btu/hr.

   a. What is the space heating load per degree day?

   b. What is the heating load in the month of March?

   c. What is the annual heating load?

5. A house has four occupants.

   a. What is the daily hot water load?

   b. What is the hot water load in January?

6. Calculate the total heat load (space and water heating) for January for the house described below:

   Location: Macon, Georgia

   Construction:

	U	Total Area
Walls	.07	1920 ft^2
Windows	1.13	75 ft^2
Doors	.49	56 ft^2
Ceiling	.05	1500 ft^2
Floor	.17	1500 ft^2

   Number of occupants: four

Formulas Used in Calculating Building Heat Load

$$U = \frac{1}{R_T}$$

$$R = \frac{1}{k} \times \text{material thickness}$$

$$h = UA\,(T_R - T_O)$$

$$\text{Space Heating Load, Btu/DD} = \frac{\text{Heat loss rate, Btu/hr}}{\text{Design temperature difference}} \times 24 \text{ hr/day}$$

$$\text{Monthly Heating load} = \text{Space Heating Load} \times \text{Monthly degree days}$$

$$\text{Annual Heating load} = \text{Space Heating Load} \times \text{Annual Number of degree days}$$

$$\text{Daily Hot Water load} = \text{Number of house occupants} \times 16{,}680 \text{ Btu/person/day}$$

TABLE 1

Values of R, U, and 1/k for Some Structural and Finish Materials, Glass, Doors, Insulation, Air Spaces, and Surface Air Films†

Materials		1/k	R	U
Wood bevel siding, .5 x 8, lapped			0.81	
Wood siding shingles, 16" x 7.5" exposure			0.87	
Asbestos-cement shingles			0.21	
Stucco		0.20		
Building paper			0.06	
½" nail-base insulation board sheathing			1.14	
Insulation board sheathing, regular density		2.63		
Plywood		1.24		
¼" hardboard			0.18	
Softwood board		1.25		
Concrete blocks, 3 oval cores				
Cinder	4" thick		1.11	
Aggregate	12" thick		1.89	
	8" thick		1.72	
Sand and gravel aggregate, 8" thick			1.11	
Lightweight aggregate, 8" thick			2.00	
Concrete blocks, 2 rectangular cores				
Sand and gravel aggregate, 8" thick			1.04	
Lightweight aggregate, 8" thick			2.18	
Common brick		0.20		
Face brick		0.11		
Sand-and-gravel concrete		0.08		
Gypsumboard (plasterboard)		0.90		
.5" lighweight-aggregate gypsum plaster			0.32	
25/32" hardwood finish flooring			0.68	
Asphalt, linoleum, vinyl, or rubber floor tile			0.05	
Carpet and fibrous pad			2.08	
Carpet and foam rubber pad			1.23	
Asphalt roof shingles			0.44	
Wood roof shingles			0.94	
3/8" built-up roof			0.33	
Basement floor below grade				0.06
Glass				
Single				1.13
Double	¼" air space			0.65
	½" air space			0.58
Triple	¼" air spaces			0.47
	½" air spaces			0.36
Storm windows (¼" air space)				0.56

†From ASHRAE Handbook of Fundamentals.

TABLE 1 (Continued) †

Solid Wood Slab Door U Values:	No Storm Door	Storm Door	
		Wood	Metal
1.00" thick	0.64	0.30	0.39
1.25" thick	0.55	0.28	0.34
1.50" thick	0.49	0.27	0.33
2.20" thick	0.43	0.24	0.29

Insulation:	1/k	R	U
0" thick		0	
2.0-2.75" thick	3.58	7	
3.0-3.5" thick	3.58	11	
3.5-3.625" thick	3.58	13	
5.25-6.5" thick	3.58	19	
6.0-7.0" thick	3.58	22	

Approximate U values for ceiling, walls, and floors (other than concrete slabs) with given insulation (R value). If heating unit is in the basement and if ducts or pipes are uninsulated, no floor loss calculation is necessary. For floors over unheated basements, use 1/3 of the approximate U value given or 1/3 of the calculated U value. For floors over unvented crawlspaces with insulated crawlspace walls, use 1/2 of the approximate U value given or 1/2 of the calculated U value. For floors over vented crawl spaces or other open spaces, use the approximate U value given or the calculated U value. Use of the approximate U values given here for a given R value will usually result in a higher heat load than will actually be the case.	0 7 11 13 19 22	0.28* 0.11 0.08 0.07 0.05 0.045

Concrete Slab Floors: Use linear feet of exposed length of slab edge in place of A:h=U (lin. ft) ΔT		
1" x 24" insulation		0.21
1" x 12" insulation		0.46
No insulation		0.81

Air Spaces (3/4")				
	Heat Flow Up	Non-reflective	0.87	
		Reflective, 1 surface**	2.23	
	Heat Flow Down or horizontal	Non-reflective	1.01	
		Reflective, 1 surface**	3.50	

*When R=0, actual U values may range from 0.2 to 0.5.
**The addition of a second reflective surface facing the first reflective surface increases the thermal resistance values of an air space only 4 to 7%.
†From ASHRAE Handbook of Fundamentals.

TABLE I (Continued)†

			R	U
Surface Air Films	Heat Flow Up	Non-reflective	0.61	
		Reflective	1.32	
	Heat Flow Down	Non-reflective	0.92	
		Reflective	4.55	
	Heat Flow Horizontal	Through vertical surface, non-reflective	0.68	
	Outside (15 mph wind)		0.17	

†From ASHRAE Handbook of Fundamentals.

EXAMPLE 1

In this example, calculations are made to determine the U value of an exterior wall. The 1/k, R, and U values are given in Table 1.

	Thickness inches	1/k	R Value	
			Uninsulated	Insulated
Outside surface air film (15 mph)			0.17	0.17
Wood bevel siding, 1/2 x 8, lapped			0.81	0.81
Ins. Bd. sheathing, reg. density	.5	2.63	1.32	1.32
Air space	3.5		1.01	
Insulation	3.5		0.00	11
Gypsumboard	.5	0.90	0.45	0.45
Inside surface air film			0.68	0.68
Totals (Σ)			4.44	14.43

For the uninsulated wall, $U = 1/\Sigma R = 1/4.44 = 0.23$ Btu/(hr)(ft^2)($^\circ$F), which is lower than the approximate value of 0.28 given in Table I. For the insulated wall, $U = 1/\Sigma R = 1/14.34 = 0.07$ Btu/(hr)(ft^2)($^\circ$F), which compares to the value of 0.08 given in Table I. Variations can occur with the materials used in the wall.

STATE AND STATION	NORMAL TOTAL HEATING DEGREE DAYS (Base 65°)													Design T_o °F	
	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	ANNUAL	WIN.	SUMM.
CALIF: Eureka	270	257	258	329	414	499	546	470	505	438	372	285	4643	32	67
Fresno	0	0	0	78	339	558	586	406	319	150	56	0	2492	28	101
Long Beach	0	0	12	40	156	288	375	297	267	168	90	18	1711	36	87
Los Angeles	28	22	42	78	180	291	372	302	288	219	158	81	2061	42	94
Mt. Shasta	25	34	123	406	696	902	983	784	738	525	347	159	5722		
Oakland	53	50	45	127	309	481	527	400	353	255	180	90	2870	35	85
Point Arguello	202	186	162	205	291	400	474	392	403	339	298	243	3595		
Red Bluff	0	0	0	53	318	555	605	428	341	168	47	0	2515		
Sacramento	0	0	12	81	363	577	614	442	360	216	102	6	2773	30	100
Sandberg	0	0	30	202	480	691	778	661	620	426	264	57	4209		
San Diego	6	0	15	37	123	251	313	249	202	123	84	36	1439	42	86
San Francisco	81	78	60	143	306	462	508	395	363	279	214	126	3015	42	80
Santa Catalina	16	0	9	50	165	279	353	308	326	249	192	105	2052		
Santa Maria	99	93	96	146	270	391	459	370	363	282	233	165	2967	32	85
COLO: Alamosa	65	99	279	639	1065	1420	1476	1162	1020	696	440	168	8529	-17	84
Colorado Springs	9	25	132	456	825	1032	1128	938	893	582	330	84	6423	- 1	90
Denver	6	9	117	428	819	1035	1132	938	887	558	288	66	6283	- 2	92
Grand Junction	0	0	30	313	786	1113	1209	907	729	387	146	21	5641	8	96
Pueblo	0	0	54	326	750	986	1085	871	772	429	174	15	5462	- 5	96
CONN: Bridgeport	0	0	66	307	615	986	1079	966	853	510	208	27	5617	4	90
Hartford	0	6	99	372	711	1119	1209	1061	899	495	177	24	6172	1	90
New Haven	0	12	87	347	648	1011	1097	991	871	543	245	45	5897	5	88
DEL: Wilmington	0	0	51	270	588	927	980	874	735	387	112	6	4930	12	93
FLA: Apalachicola	0	0	0	16	153	319	347	260	180	33	0	0	1308		
Daytona Beach	0	0	0	0	75	211	248	190	140	15	0	0	879	32	94
Fort Myers	0	0	0	0	24	109	146	101	62	0	0	0	442	38	94
Jacksonville	0	0	0	12	144	310	332	246	174	21	0	0	1239	29	96
Key West	0	0	0	0	0	28	40	31	9	0	0	0	108	55	90
Lakeland	0	0	0	0	57	164	195	146	99	0	0	0	661	35	95
Miami Beach	0	0	0	0	0	40	56	36	9	0	0	0	141	45	91
Orlando	0	0	0	0	72	198	220	165	105	6	0	0	766	33	96
Pensacola	0	0	0	19	195	353	400	277	183	36	0	0	1463	29	92
Tallahassee	0	0	0	28	198	360	375	286	202	36	0	0	1485	25	96

NORMAL TOTAL HEATING DEGREE DAYS (Base 65°)														Design T_o °F	
STATE AND STATION	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	ANNUAL	WIN.	SUMM.
FLA: Tampa	0	0	0	0	60	171	202	148	102	0	0	0	683	36	92
West Palm Beach	0	0	0	0	6	65	87	64	31	0	0	0	253	40	92
GA: Athens	0	0	12	115	405	632	642	529	431	141	22	0	2929	17	96
Atlanta	0	0	18	127	414	626	639	529	437	168	25	0	2983	18	95
Augusta	0	0	0	78	333	552	549	445	350	90	0	0	2397	20	98
Columbus	0	0	0	87	333	543	552	434	338	96	0	0	2383	23	98
Macon	0	0	0	71	297	502	505	403	295	63	0	0	2136	23	98
Rome	0	0	24	161	474	701	710	577	468	177	34	0	3326	16	97
Savannah	0	0	0	47	246	437	437	353	254	45	0	0	1819	24	96
Thomasville	0	0	0	25	198	366	394	305	208	33	0	0	1529		
IDAHO: Boise	0	0	132	415	792	1017	1113	854	722	438	245	81	5809	4	96
Idaho Falls 46W	16	34	270	623	1056	1370	1538	1249	1085	651	391	192	8475		
Idaho Falls 42NW	16	40	282	648	1107	1432	1600	1291	1107	657	388	192	8760		
Lewiston	0	0	123	403	756	933	1063	815	694	426	239	90	5542	6	98
Pocatello	0	0	172	493	900	1166	1324	1058	905	555	319	141	7033	- 8	94
ILL: Cairo	0	0	36	164	513	791	856	680	539	195	47	0	3821		
Chicago	0	0	81	326	753	1113	1209	1044	890	480	211	48	6155	- 3	94
Moline	0	9	99	335	774	1181	1314	1100	918	450	189	39	6408	- 7	94
Peoria	0	6	87	326	759	1113	1218	1025	849	426	183	33	6025	- 2	94
Rockford	6	9	114	400	837	1221	1333	1137	961	516	236	60	6830	- 7	92
Springfield	0	0	72	291	696	1023	1135	935	769	354	136	18	5429	- 1	95
IND: Evansville	0	0	66	220	606	896	955	767	620	237	68	0	4435	6	96
Fort Wayne	0	9	105	378	783	1135	1178	1028	890	471	189	39	6205	0	93
Indianapolis	0	0	90	316	723	1051	1113	949	809	432	177	39	5699	0	93
South Bend	0	6	111	372	777	1125	1221	1070	933	525	239	60	6439	- 2	92
IOWA: Burlington	0	0	93	322	768	1135	1259	1042	859	426	177	33	6114	- 4	95
Des Moines	0	9	99	363	837	1231	1398	1163	967	489	211	39	6808	- 7	95
Dubuque	12	31	156	450	906	1287	1420	1204	1026	546	260	78	7376	-11	92
Sioux City	0	9	108	369	867	1240	1435	1198	989	483	214	39	6951	-10	96
Waterloo	12	19	138	428	909	1296	1460	1221	1023	531	229	54	7320	-12	91

UNIT SB-8
PROGRESS CHECK (C-1)
WRITTEN QUIZ

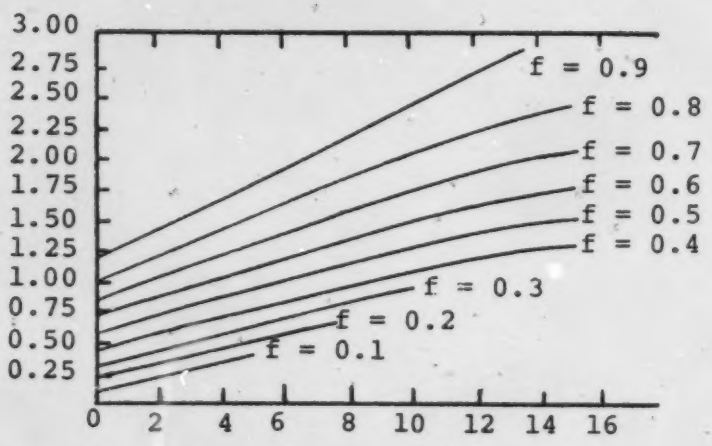
1) The first component of the solar system that should be sized is the _____.

2) The rule of thumb for sizing collectors based on residence floor area is that the collector area should be _____ to _____ of the floor area.

3) A procedure of sizing collectors that distinguishes between air and liquid systems, and different tilt angles is the sizing procedure developed by _____.

4) In the F-Chart method, "f" stands for _____.

5) Using the graph below, determine f when x = 10, y = 1.5.



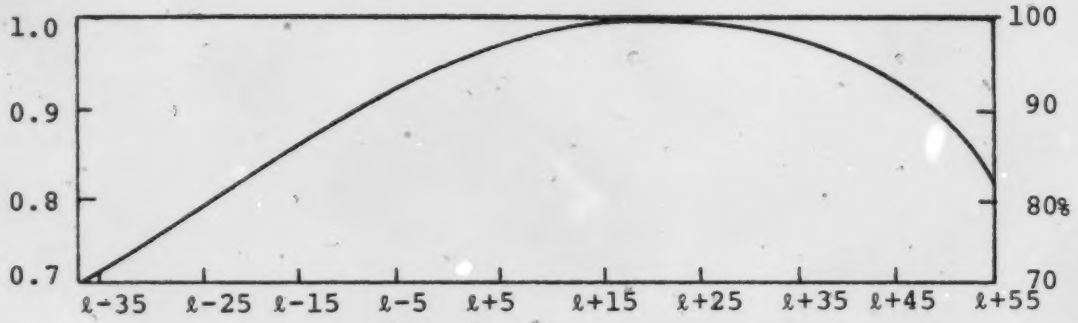
6) X represents _____ divided by _____.

7) Y represents _____ divided by _____.

8) Collector efficiency is a measure of the ability of a collector to _____ and _____ heat energy.

9) Using the graph and formula below, determine the increased collector area that is necessary when the tilt angle is 30° for a solar space heating installation in an area where the latitude is 45°.

$$a = \frac{1}{e} - 1$$



10) The _____ sizing method sizes collectors by use of curves generated by a computer in which specific system parameters are fed.

UNIT SB-8
PROGRESS CHECK (C-2)
PEER QUIZ

a. The rule of thumb for liquid collector flow rate is _____ gpm/ft^2 of collector.

b. The rule of thumb for estimating water storage size is _____ to _____ gallons/ft^2 of collector.

c. With reference to heat exchangers, the _____ _____ is the difference between the temperature of incoming collector fluid and outgoing fluid to the storage tank. This difference should be about _____ ^{o}F.

d. Collector efficiency (increases, decreases) as approach temperature decreases.

e. An open tank is different from an air cushion tank in that _____.

f. Corrosion due to absorbed air is minimal in a _____ tank.

g. To select a duct coil, air velocity across the coil should range from _____ to _____ feet per minute.

h. To select a duct coil, storage temperature should be at least _____.

UNIT SB-8
UNIT TEST

1) Indicate whether each statement is true or false by circling T (true) or F (false).

a. T F When determining the size of solar heating system components, the heat storage unit is sized first and all other components are sized in relation to it.

b. T F For space heating only, the optimum tilt angle for a collector is local latitude plus 15°.

c. T F The larger the approach temperature of the heat exchanger, the higher is collector efficiency.

d. T F In an air cushion tank, the heated liquid can expand without increasing system pressure because the tank is open to the atmosphere.

e. T F The F-Chart sizing technique requires information about characteristics specific to a given solar system.

f. T F The Los Alamos LC sizing method has separate divisors for air and liquid collector systems.

g. T F Most collector sizing methods make about the same assumptions, and take into account the same factors.

h. T F Collectors should be oriented to face south.

i. T F Liquid expansion due to heating is greater for a ethylene glycol solution than for pure water.

j. T F Research data suggests that a solar system that satisfies 80 to 90% of the heating requirements will be the most economical installation.

k. T F In the northern hemisphere, collector area is usually greater if solar energy is needed in the winter, rather than in the summer.

2) Complete each statement with the best answer.

a. A rule of thumb for sizing collector area is that the collector area should be from _____ to _____ the floor area of the home.

b. In an F-Chart, the X value is the ratio of _____ over _____.

c. In the F-Chart collector sizing method, "f" represents _____.

d. A heat exchanger is used in the collector loop of a liquid system for the purpose of _____.

e. Most heat exchangers have an approach temperature of about _____°F.

f. To size collector loop heat exchangers, the collector loop flow rate should be _____ gpm per square foot of installed collector.

g. To select an air heating coil, storage water temperature should range from _____ to _____°F.

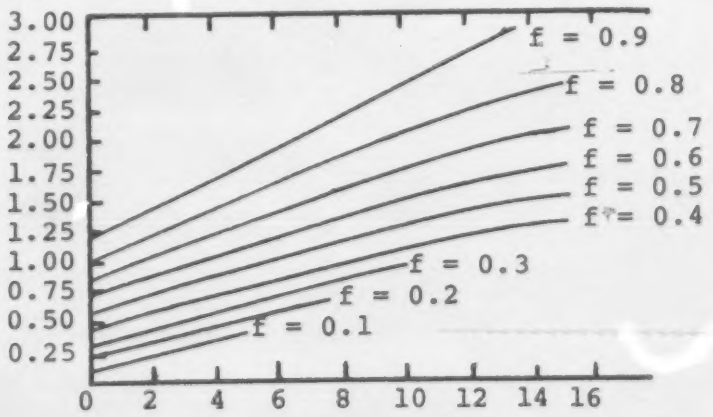
h. For a domestic hot water heating only, the collector tilt angle should be _____.

i. A rule of thumb for sizing liquid storage units is that they should hold _____ to _____ gallons per square foot of collector area.

j. The solar system sizing technique that has been programmed for computer use is the _____ method.

k. The kind of expansion tank which allows the least amount of air absorption in the liquid is the _____ _____ _____ tank.

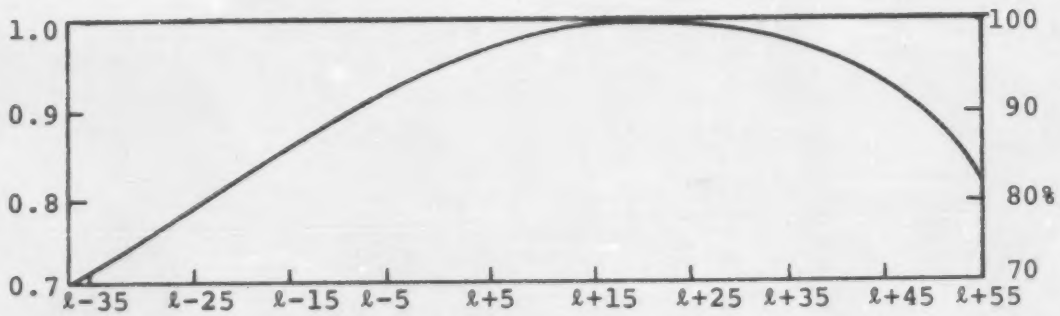
3) In the F-Chart below, if x = 4, and y = 1.00, what is the solar system's heating contribution?



4) If the Btu input to a collector is 300 Btu/ft^2/hr and the Btu output from the collector is 200 Btu/ft^2/hr, what is the collector efficiency?

5) Using the formula and graph below, determine the increase in collector area necessary when the collector in a solar heating system is tilted 15° in a location whose latitude is 40°.

$$a = \frac{1}{e} - 1$$



a. If gas costs $0.40/therm and a gas furnace is 60 percent efficient, what is the energy cost?

b. Assuming an 8 percent annual rate of inflation in natural gas costs, what will be the energy cost in 20 years for the case described in question a?

c. What is the current cost of natural gas in your area?

d. Estimate the cost of a complete solar system with a collector area of 500 ft^2.

e. List below the financial costs and benefits which should be included in calculating the annual cost of a solar system.

f. A family borrows $9,000 from a bank for 18 years at a 9 percent interest rate. What is their annual mortgage payment? Use the figure provided on the next page.

A building in Atlanta, Georgia has an annual space heating load of 87. mBtu, and a water heating load of 15 mBtu. A solar system for the building having 350 ft^2 of collector is calculated to provide 60 percent of the annual heating load. System cost is estimated at \$25/ft^2 of collector area. Electricity at 4¢/kWh is available and electric auxiliary heating will be used.

The terms of the loan are 20 years at 9 percent with 20 percent downpayment. Property tax amounts to 4 percent of one-half of the market value of the system, insurance is 0.005 of the installed cost, and the owner's income tax bracket is 25 percent for federal and 8 percent for the state income tax return. The electricity to operate the system is 4 percent of the total energy delivered as useful heat, and maintenance cost is \$90 for the first year.

Electricity is estimated to escalate at 9 percent per year, and the general inflation rate will also beat 7 percent. Perform an economic analysis for the first ten years of this system, including a cash flow analysis and an economic summary. Determine the time of positive savings.

LIFE-CYCLE COST ANALYSIS
LCA-1 WORKSHEET — BASIC DATA

BUILDING DATA

Line 1. Building Annual Heat Load
(from Col. C Total of Step 2A Worksheet in EQUIPMENT SELECTION Section) ..... _____ mBtu

Line 2. Hot Water Load
(from Col. D Total of Step 2A Worksheet in EQUIPMENT SELECTION Section) ..... _____ mBtu

Line 3. Total Annual Heating Load
(Line 1 _____) + (Line 2 _____) = ... _____ mBtu

SOLAR SYSTEM DATA

Line 4. Collector Area
(from Line 7 of Step 2B Worksheet in EQUIPMENT SELECTION Section) ..... _____ sq. ft.

Line 5. Fraction of Annual Heating Load Carried by Solar
(from Line 14 of Step 2B Worksheet in EQUIPMENT SELECTION Section) ..... _____ %

Line 6. Unit Cost of Solar System Installed ..... _____ $/sq. ft.

Line 7. Installed Cost of Solar System:
(Line 4 _____) x (Line 7 _____) = ... _____ $

Line 8. Type of Auxiliary Fuels:
8a. Space _____ 8b. Hot Water _____

Line 9. Efficiencies of Auxiliary Fuels:
9a. Space _____ % 8b. Hot Water _____ %

Line 10. Auxiliary Fuel Costs (from Figs. 1 & 2):
10a. Space _____ $/mBtu 10b. Hot Water _____ $/mBtu

FINANCIAL DATA

Line 11. Terms of Loan: Years _____ Interest Rate _____ %

Line 12. Down Payment on Loan: (_____ %) x (Line 7 _____) = ... _____ $

Line 13. Amount of Loan: (Line 7 _____) — (Line 12 _____) = ... _____ $

Line 14. Annual Mortgage Payment:
(Factor from Fig. 4 _____) x (Line 13 _____) = ... _____ $/year

TAXES AND INSURANCE

Line 15. Property Tax:
15a. Ratio of Taxable Value to Installed Cost _____ %
15b. Property Tax Rate _____ %
15c. Property Tax:
(Line 7 _____) x (Line 15a. _____) x (Line 15b. _____) = ... _____ $/year

Line 16. Income Tax Rate:
16a. Federal Tax Rate _____ %
16b. State Tax Rate _____ %
16c. Effective Income Tax Rate:
(Line 16a. _____) + (Line 16b. _____) — [2 x (Line 16a. _____)
x (Line 16b. _____)] = ... _____ %

Line 17. Insurance:
(Line 7 _____) x (Insurance Rate _____) = ... _____ $/year

OPERATION AND MAINTENANCE

Line 18. First Year Operating Cost:
18a. Annual Solar Heat Supplied:
(Line 5 _____) x (Line 3 _____) = _____ mBtu
18b. Fraction of Solar for Electricity _____ %
18c. Operating Cost:
(Line 18a. _____) x (Line 18b. _____) x (Line 10a. _____) = ... _____ $/year

Line 19. First Year Maintenance Cost = ... _____ $/year

NON-SOLAR SYSTEM DATA

Line 20. First Year Fuel Expenses:
20a. Space: (Line 1 _____) x (Line 10a. _____) = ... _____ $/year
20b. Hot Water: (Line 2 _____) x (Line 10b. _____) = ... _____ $/year
20c. Total Fuel Expenses:
(Line 20a. _____) + (Line 20b. _____) = ... _____ $/year

Line 21. First Year Operating Expenses:
(Line 20c. _____) x (_____ %) = ... _____ $/year

Line 22. First Year Fuel and Operating Expenses:
(Line 20c. _____) + (Line 21. _____) = ... _____ $/year

LIFE-CYCLE COST ANALYSIS
LCA-2 WORKSHEET — SOLAR CASH FLOWS

KEY:

Annual Mortgage Rate _____ %
(from Line 11)

Auxiliary Inflation Rate _____ %

General Inflation Rate _____ %

Collector Area _____ sq. ft.
(from Line 4)

Solar Fraction of Total Load _____ %
(from Line 5)

System Cost _____ $
(from Line 7)

Down Payment _____ $
(from Line 12)

Col. A	Column B	Column C	Column D	Column E	Column F	Column G	Column H	Column I	Column J	Column K	Column L
YEAR	ANNUAL MORTGAGE PAYMENT (from Line 14)	YEARS LEFT ON MORTGAGE	FRACTION OF MORTGAGE AS INTEREST (from Fig. 4)	INTEREST PAID (Col. B x Col. D)	AUXILIARY FUEL COST (See Note 1.)	PROPERTY TAX (See Note 2.)	INSURANCE (See Note 3.)	OPERATING COST (See Note 4.)	MAINTENANCE COST (See Note 5.)	INCOME TAX SAVINGS (Col. E x Line 16c.)	EXPENSE WITH SOLAR (See Note 6.)
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											

Note 1. First year cost:
(Line 3 _____) x (1.0 — Line 5 _____) x (Line 10a. _____)
Second and future years: (Previous Year Cost) x (1 + Fuel Inflation Rate)

Note 2. First Year Cost: (Line 15c.)
Second and Future Years: (Previous Year Cost) x (1 + General Inflation Rate)

Note 3. First Year Cost: (Line 17)
Second and future years: (Previous Year Cost) x (1 + General Inflation Rate)

Note 4. First Year Cost: (Line 18)
Second and Future Years: (Previous Year Cost) x (1 + Fuel Inflation Rate)

Note 5. First Year Cost: (Line 19)
Second and Future Years: (Previous Year Cost) x (1 + General Inflation Rate)

Note 6. First Year Cost:
(Down Payment) + (Col. B) + (Col. F) + (Col. G) + (Col. H) + (Col. I) + (Col. J) — (Col. K)
Second and Future Years: (Cols. B+F+G+H+I+J—K)

LIFE-CYCLE COST ANALYSIS
LCA-3 WORKSHEET — ECONOMIC SUMMARY

KEY:

Fuel Inflation Rate _____%

COLM	Column N	Column O	Column P	Column Q	Column O	Column P	Column Q	Column O	Column P	Column Q
YEAR	NON-SOLAR SYSTEM	SOLAR SYSTEM								
		COLLECTOR AREA _____ sq ft			COLLECTOR AREA _____ sq ft			COLLECTOR AREA _____ sq ft		
	FUEL PLUS OPERATING EXPENSE (See Note 1)	EXPENSE WITH SOLAR (From Col. L)	SAVINGS WITH SOLAR (Col. N) — (Col. O)	CUMULATIVE SAVINGS WITH SOLAR (See Note 2)	EXPENSE WITH SOLAR (From Col. L)	SAVINGS WITH SOLAR (Col. N) — (Col. O)	CUMULATIVE SAVINGS WITH SOLAR (See Note 2)	EXPENSE WITH SOLAR (From Col. L)	SAVINGS WITH SOLAR (Col. N) — (Col. O)	CUMULATIVE SAVINGS WITH SOLAR (See Note 2)
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										

Note 1. First Year Cost: (Line 22)
Second and Future Years:
(Previous Year Cost) x (1 + Fuel Inflation Rate)

Note 2. First Year Savings: (Col. P First Year)
Second and Future Years:
(Previous Year) + (Col. P)

UNIT SB-10
PROGRESS CHECK (C-1)
(PEER QUIZ)

The student should be quizzed on the following questions:

Assignment Sheet SB-6-2: questions b, f, g

Assignment Sheet SB-6-4: questions c, f

Assignment Sheet SB-6-6: questions a, c, d, e, f

The student must answer eight out of ten questions correctly to pass the Progress Check.

UNIT SB-10
UNIT TEST

1) Indicate whether each statement is true of false by circling T (true) or F (false).

a. T F In a thermosiphon system, heated water settles and flows down into the storage tank.

b. T F A thermosiphon system can never be used in freezing climates.

c. T F A collector storage temperature difference of about 10^{o} F usually starts the pump in circulating systems.

d. T F A freeze protection system should be designed to avoid reliance on electrical power.

e. T F The heating coil for auxiliary water heating should be located at the bottom of the storage tank.

f. T F A two-tank DHW system makes more efficient use of electric energy than a one-tank system.

g. T F Air collectors can be used only in direct DHW systems.

h. T F A fan in an air heating DHW system requires more energy than the pumps used in liquid systems.

i. T F A DHW system can use solar energy only in the winter.

2) Complete each statement as precisely as you can.

a. In a thermosiphon system, the storage tank must be located _____.

b. A thermosiphon system is a (direct, indirect) water heating system.

c. In direct heating, pump circulating systems, excessive pressure in the system may be relieved by installing _____ in the collector loop.

d. Drain-down is used for the purpose of _____ _____.

e. Indirect DHW systems are distinguished from direct hot water systems in that they include _____ in the liquid in the collector loop, and must always include a _____ as a component in the collector loop.

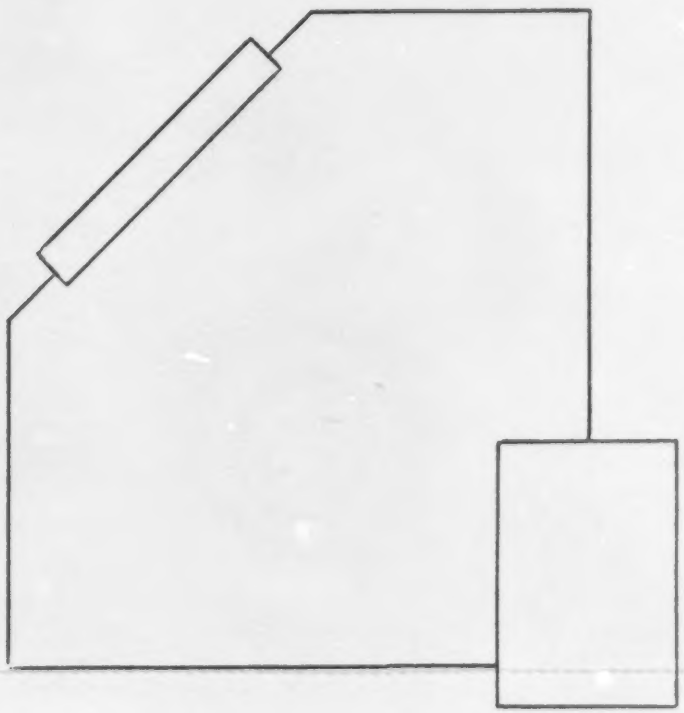
f. To prevent excessively hot water from entering the DHW service line, a _____ is installed between the solar and conventional hot water tanks.

g. Two devices used to avoid excessive pressure in the storage tank are the _____ and the _____.

h. In DHW systems, the heat exchanger must always be constructed so as to be _____.

i. A _____ to _____ gallon water tank is usually adequate for solar DHW systems.

3) The diagram below illustrates an incomplete direct heating/ circulating DHW system with drain-down capability. Label each component shown, and the direction of hot and cold water flow. Draw in and label the components and piping necessary for completing the system.



UNIT TEST
UNIT SC-1

Part I. (50 points)

Write a brief report on your contributions to the two demonstration projects in Job Sheets SC-1.2, SC-1-3. Come to an agreement with your instructor regarding the grade your efforts deserve. This grade will count for half your grade on this unit.

Part II. (50 points)

1. Suppose a certain house has 200 ft^2 of south-facing window. If the contribution of double glazing is 18.8 $Btu/ft^2/hr$, what is the total heating contribution of this glazing during a 200-day heating season? (4 points)

2. Approximately how much heat capacity should be available for good use of this net gain? Suppose half is to be met with surfaces exposed to sunlight, and half from surfaces indirectly heated. (4 points)

3. Take a total heat capacity, needed for use of the direct solar gain, of 15,000 $Btu/^oF$. If stone concrete has a heat capacity of 31.7 $Btu/ft^3/^oF$, what area of 6" slab would provide this? (5 points)

4. What is the minimum recommended distance between upper and lower vents in a Trombe wall?
(4 points)

5. What is the function of the backdraft damper in lower vents of Trombe walls and thermosiphoning air heaters?
(4 points)

6. Wood separators are recommended between glazing surface and the Trombe wall or the collector surface of the air heater. Why are these necessary?
(4 points)

7. Why is a thermosiphoning air heater most efficient when used in schools or low-rise office buildings?
(5 points)

8. Why is glass recommended for the glazing on the thermosiphoning air heater, rather than plastic?
(3 points)

9. Which produces more Btu/ft^2/hr--the air heater or the Trombe Wall?
(4 points)

10. Which installation is more suitable for use on existing buildings?
(4 points)

11. About how much time lag is there between the maximum air temperature delivered by the Trombe Wall by convection, and the maximum heat delivered by radiation?
(4 points)

12. Why is the Trombe Wall a good choice for new residential construction?
(5 points)

1) For each question, circle true (T) or false (F).

a. T F Legislation controlling street layouts can encourage the use of solar systems.

b. T F The orientation of a building does not affect the ease with which collector arrays can be installed.

c. T F Insurance rates for solar and non-solar homes are similar.

d. T F Solar system building codes are readily available and contain standards specific to solar systems.

e. T F The local building inspector should initially be contacted when the installation is complete and ready for inspection.

f. T F Where local solar building codes are absent, Underwriters Laboratory certification may be required where it applies to solar systems.

g. T F Most financial institutions have established policies with regard to financing solar systems.

h. T F Most homeowners and individuals in the building construction business understand the functioning and benefits of solar systems.

i. T F A storage tank placed in the basement can usually be placed on the 4-inch concrete slab poured for basement floors.

j. T F For basement installation in new construction, the storage tank is placed before floor girders are assembled.

k. T F Collectors should be carefully inspected before installation.

l. T F Insulation is normally done before leak-testing.

2) After each step of house construction listed below, list the letter of the step of solar system installation that occurs simultaneously.

Steps in House Construction

Construction of basement floor _____

Roofing and flashing _____

Rough plumbing _____

Plumbing leak-testing _____

Rough electrical wiring installed _____

House insulation _____

Steps in Solar System Installation

a. Control panel installed

b. Piping insulation

c. Placing collectors on the roof (for collectors integrated with the roof)

d. Construction of base for storage tank

e. Collector loop leak-testing

f. Heat exchanger installed and piped

1) Indicate whether each of the following statements is true by circling true (T) or false (F).

a. T F A spherical storage tank is usually the most practical shape for a storage tank.

b. T F Steel tanks must be lined with butyl rubber for insulation.

c. T F Storage tanks must withstand temperatures of at least 90^{o} F.

d. T F In basement installations, the bottom of the storage tank should be placed directly on the concrete slab base.

e. T F In new construction, a liquid storage tank is usually installed before floor joists are built.

f. T F Insulation of at least R-30 is recommended for storage tanks placed outdoors.

g. T F The storage tank should be carefully insulated before it is filled.

h. T F Tank-piping connections should be made by welding the piping to its opening in the tank.

i. T F Even storage tanks that are located indoors must be insulated.

j. T F If the collector array is on the roof, the storage tank can always be supported by the attic floor.

2) List five steps in liquid storage tank installation.

1)

2)

3)

4)

5)

UNIT SC-4
PROGRESS CHECK (C-1)
PEER QUIZ

The student should be quizzed on the following questions:

from Assignment Sheet SC-4-1: 1a, 1d, 2c, 2e

from Assignment Sheet SC-4-2: 1a, 1c, 1e, 1i, 1j

from Assignment Sheet SC-4-3: 1

1. For each statement, circle true (T) or false (F).

   a. T F In Georgia, true South and magnetic South are the same.

   b. T F Solar collectors should be oriented to face true South.

   c. T F Before roof mounting collectors, it is importnat to determine that the roof can bear the weight of the collectors.

   d. T F In roofs being constructed, the collectors are mounted on top of the roof felt.

   e. T F In retrofit systems, if roof angle is appropriate, the collectors should always be mounted directly on top of the shingles.

   f. T F Pitch pots are used with tilted roofs whose tilt angle is almost optimal for the collectors.

   g. T F Supports for ground mounting must be established above the frost line.

   h. T F Spanner mounting is used when there is no access to attic space.

   i. T F Mounting bolts for spanner mounts are installed directly above the rafter.

   j. T F Lag screws should penetrate at least 2-inches into the rafters.

2. Fill in the best answer(s) to complete each statement.

   a. True and magnetic South are indicated on _____ _____ _____ maps.

   b. Collector arrays must be sited to receive a minimum of _____ hours of sunlight.

   c. A solar easement is: _____ _____.

d. Four factors to be considered in siting collectors are:

e. Three basic considerations when mounting collectors on the roof are:

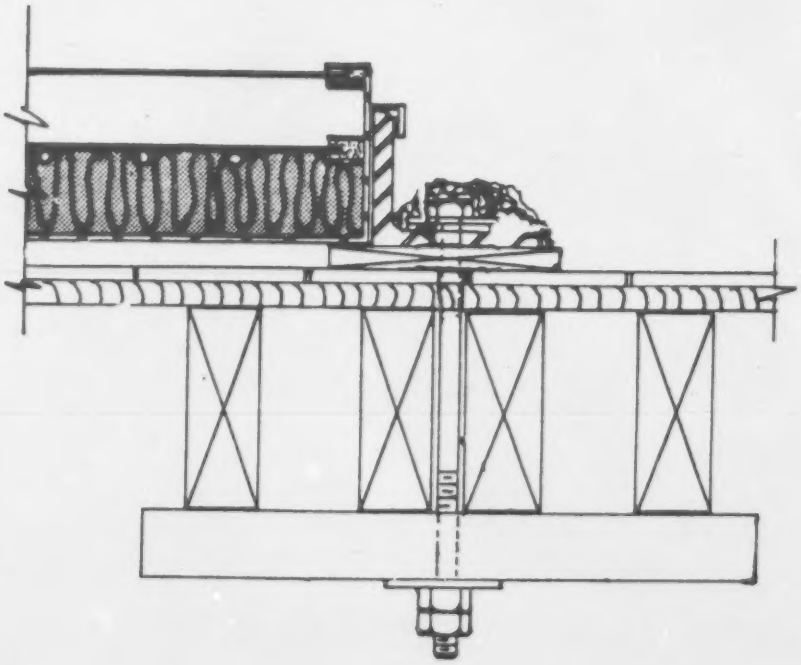
f. Roof leakage through lagscrews penetrating the roof is prevented by _____
_____.

g. Ground mounted collectors are sometimes fenced in to:
_____
_____.

h. Lag screws used in lag screw mountings should be at least _____ inch in size.

3. In the spanner mounting detailed below, label the following:

mounting block
mounting bolt
spacer blocks
spanner
rafter
roofing cement
nuts



UNIT SC-5
UNIT TEST

1. Collectors must be inspected when they arrive on site. List items to look for in examining collectors.

2. The purpose of keeping a collector covered prior to the time it is put into operation is to _____ _____.

3. The best and safest method of hoisting collectors to the roof is to _____.

4. What is a closed loop system?

5. Where are closed loop systems generally used?

6. An open loop system uses water from the cold water supply and circulates it throughout the system. How is this system normally protected from freezing?

7. Draw schematically:

   a) a parallel flow--direct return system

   b) a parallel flow--reverse return system

8. Why is the parallel flow--reverse return system preferred?

9. How do you minimize electrolytic action when two dissimilar metal pipes have to be coupled?

10. The final step after installing outside piping is to _____.

1. In the space below, diagram the piping and components in the loops from the collectors to storage, and back again. You may want to include the following components in your diagram: heat exchanger, pumps, check valve, balance valve, air separator, air separator vent, expansion tank, expansion tank relief valve, drain valve, pressure gauge, fill line and/or valve.

2. Where was the heat exchanger located?

3. What is the purpose of the expansion tank?

4. If the particular system you examined did not have an air separator, how does entrapped air get out of the system?

5. What is the purpose of the check valve located in the line between the collectors and the heat exchanger?

6. What is the purpose of the balance valve?

7. If you did not find a balance valve in your circuit, what does it tell you about your system?

8. If the glycol loop loses fluid, where and how can you refill it?

a. Two valves located on the storage tank which are part of the load side loop are:

1)

2)

b. The valve connected to both the line from the storage tank and the cold water line is the _____.

c. What is the purpose of the valve described in question (b)?

d. Was there a pump in the load side loop? _____

e. Why is no pump needed in a system designed to supply hot water only?

f. Space heating systems have two pumps in the load side circuit. What is the purpose of each pump?

1)

2)

1. T F Local codes may affect the type of heat exchanger and the valving required to protect the potable water supply.

2. T F It makes no difference which openings are used for inlet and outlet connections on shell and tube heat exchangers that are not specifically marked.

3. T F The compression tank should be located at the lowest point in the collector fluid loop (inside).

4. T F Purge lines outside the building are not insulated since heat loss is desired when fluid is circulating in these lines.

5. T F The only component of the collector fluid loop (inside) that should have an air space is the compression tank.

6. T F In the closed loop system, the line running from a hose faucet through a check valve to a cross fitting below the compression tank fitting is called a fill line.

7. State two purposes for the expansion tank in the collector fluid loop.

   1)

   2)

8. Explain the difference between an "open" and a "closed" loop system.

9. How does the closed loop system reduce the cost of anti-freeze?

10. What mechanism is used to prevent freezing in an open-loop system which is circulating tap water?

11. What is the flow rate in feet per second for a one-inch pipe carrying 15 gallons per minute?

12. What should be the operating pressure of the temperature pressure relief valve mounted in the top of the storage tank?

13. Where should a vacuum relief valve be installed?

14. Why is a check valve required in the line between collectors and the heat exchanger in the storage tank?

15. What is the purpose of a circuit setter?

The Instructor will use the Lennox RT-5 Solar Cycle Trainer and the EB-5 Solar Schematic Trainer to describe each of the conditions shown on pages 5 to 17 of the "Controls-Components and System Schematics Chapter of the Lennox Manual.

As each schematic is lighted on the two trainers, the Instructor will ask the student(s) to describe orally the function and operation of each of the energized controls to produce the fluid flow as shown.

Each condition, operating procedure and function of energized controls, is explained in "RT-5 Solar Cycle Trainer" or "EB-5 Solar Schematic Trainer," Instructor manual.

1. What is the first step required before any electrical wiring and component installation is ordered?

2. What is always the first step prior to making any electrical hook-up?

3. The second step should always be...

4. The type of control that compares the difference in temperature between collector and the storage tank and turns on or off the collector fluid loop pump is the _____ _____.

5. The two devices which provide input data to the differential controller are:

   a.

   b.

6. The electronic sensing device that provides the signal to operate the dual control valve so that excess heat is diverted away from the collector(s) and storage is called the _____ _____.

7. What two control devices must activate to provide signals so that fluid can flow through the solar heat coil from storage when no energy is available from the collectors?

   a.

   b.

8. The Honeywell Model W986A Solar Control Panel, a typical solar control, can be used to control two types of solar hydronic systems. What are these two types?

   a.

   b.

9. The Honeywell Model W968A Solar Control Panel contains switching relays, manual switches, field wiring terminals, and indicator lights. There are three main components besides those listed above. What are these components?

   a.

   b.

   c.

10. How can the difference in temperature on the differential control be changed?

11. How does a temperature sensor (thermistor) work?

12. How does an aquastat sensor work?

13. What is the purpose of the return air limit control located between the solar heat coil and the blower of the auxiliary heat furnace?

14. If pump operating amperage and voltages exceed the rating of the control equipment, what must you do?

UNIT TEST
UNIT SC-8

1. What must be done to the collectors before putting any fluid into the collector fluid loop?

2. If the requirement answered by question #1 is not accomplished what may happen?

   a.

   b.

   c.

3. How many times should the system be flushed before final charging?

4. When should leak-testing be completed?

5. Most homes in metropolitan areas built in the last fifteen years have the water line regulated to 50 psig. What must be done to utilize this full pressure in leak-testing the system?

6. If water pressure greater than 50 psig is available, should it be used for testing? Why or why not?

7. During leak-testing, how long should water be circulated?

8. Name two indicators of leaks in the system.

   a.

   b.

9. What is required to properly balance the flow through a circuit setter valve?

10. What is the minimum length of time the pumps should be run to check for leaks in each of the load side loops?

11. What does setting the collector set point potentiometer at 90° F mean to the operation of the system?

12. After all controls and wiring have been thoroughly checked out and all switches are in the "auto" position, what is the final step to putting the system in operation?

Using the "Lennox Domestic Hot Water System Chapter," p. 1-20 in the Lennox Solar Manual, devise a checklist for maintenance of the LSHW-1 Solar Water Heating System.

This list should be similar in construction to the general checklist for maintenance of a domestic water heating system shown in Figure 10-10, p. 10-8 of the Fundamentals Manual.

Upon completion of your checklist, turn it in to your instructor for review and correction.

1. The maintenance activities listed below must be accomplished on a regular basis. Match the item in Column 1 with typical service interval required in Column 2.

a. Air Filters	1. ____ Check weekly for first-month and quarterly thereafter.
b. Liquid Filters	
c. Antifreeze Solutions	2. ____ Lubricate at fixed intervals suggested by manufacturer.
d. Blower Drive Belts	
e. Pumps	3. ____ Check annually and change if worn.
f. Liquid Levels	
	4. ____ Check annually, change when color indicator changes color.
	5. ____ Change monthly for the first three months.
	6. ____ Change after first month and annually thereafter.

2. What event requires the system to be checked any time the event occurs in daylight hours?

3. In a normal maintenance inspection, what should be checked to assure each collector array is operating efficiently?

   (Student Note: Answer <u>is</u> <u>not</u> physical damage to collectors.)

4. How does a temperature sensor work?

5. If the resistance of a sensor is found to be faulty, how do you correct the problem?

6. If a sensor is immersed in liquid what must you do before replacing it?

UNIT SD-2
PROGRESS CHECK
C-1

As the student checks each operating mode of the ST-17 trainer, the Instructor will hand the student a series of electrical and plumbing flow schematics. The Instructor will keep the written material keyed to schematic. The Instructor will ask the student to select the schematic representing the condition existing on the ST-17 trainer and will ask the student to explain which valves, relays and other components are activated to cause the particular flow conditions shown. The student should not proceed to the next mode until he has selected the proper schematic and has correctly explained the operation of the electrical components.

FIRST STAGE HEAT DEMAND

(Energy Available from Collectors)

A. When the thermostat senses a demand for heat, it first closes the first stage contacts. This energizes the 1K relay coil through terminal "W1."

1. 1K5 contacts close. The circuit is complete to the furnace blower motor.

2. 1K2 contacts close. The circuit to the gas valve is not complete.

3. 1K4 contacts open. The circuit to valve V2 is not complete.

4. 1K1 open and closed contacts are reversed. This bypasses the storage sensor and places a resistor in the circuit. The collector sensor now controls the 3K relay. If the collector temperature is over 110° F the 3K relay is energized. If the collector temperature is under 110° F the relay is de-energized.

B. Since the collector temperature is over 110° F, 3K relay energizes.

1. 3K5 contacts close. The circuit to valve V2 is not complete.

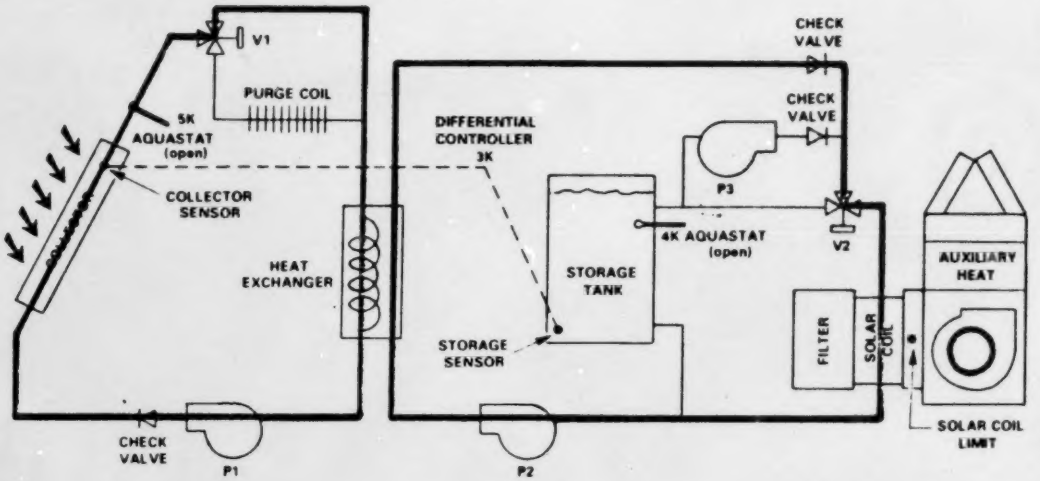
2. 3K2 contacts open. The circuit to the gas valve is not complete.

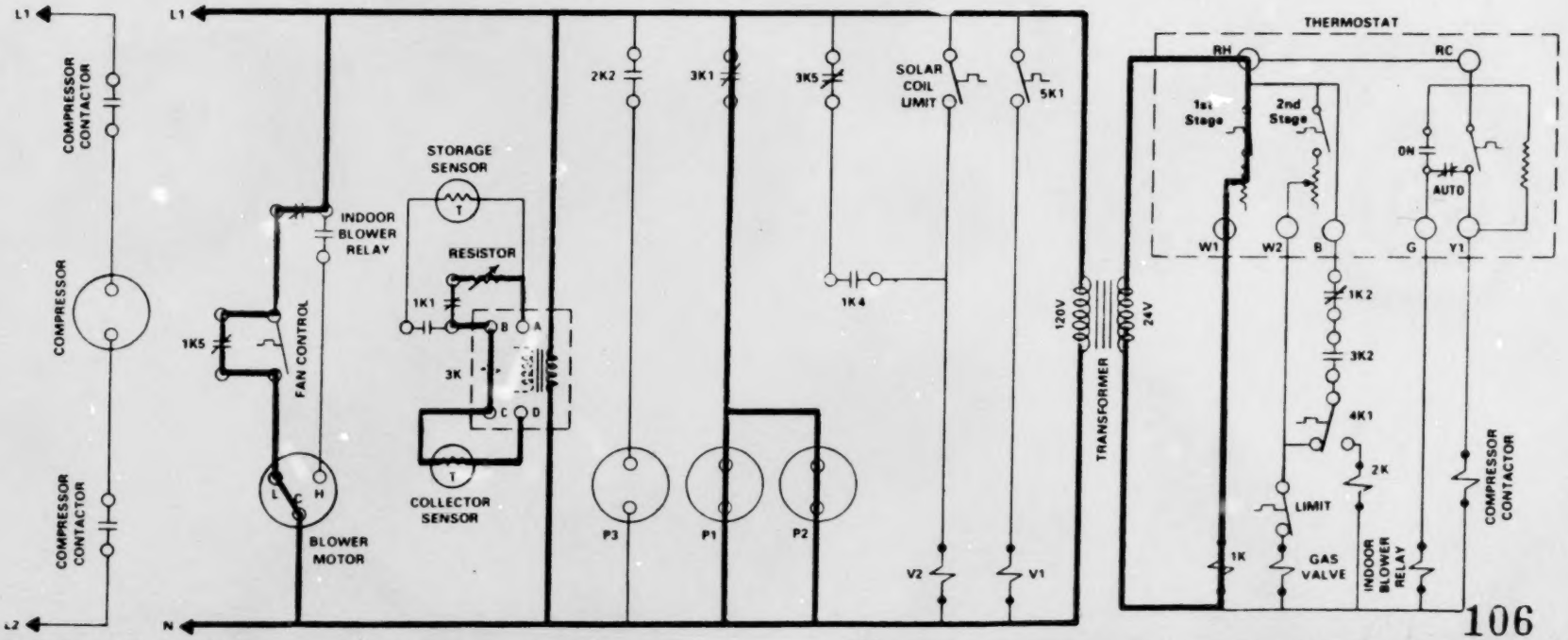
3. 3K1 contacts close completing a circuit to pumps P1 and P2.

SUMMARY: Fluid is circulated through the collector piping loop. Fluid is also circulated through the heat exchanger to the solar heat coil.

A

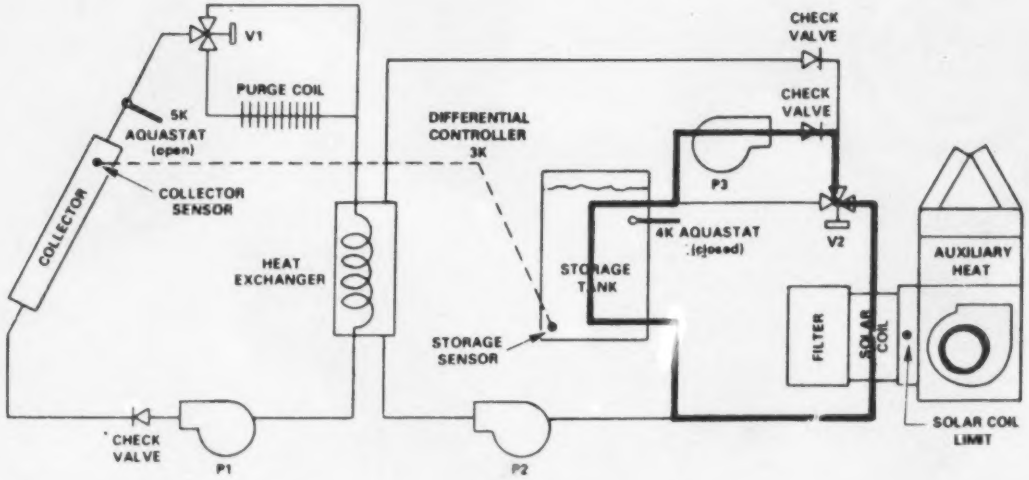
"Instructor's Materials"
UNIT SD-2
PROGRESS CHECK (C-1)
ORAL QUIZ

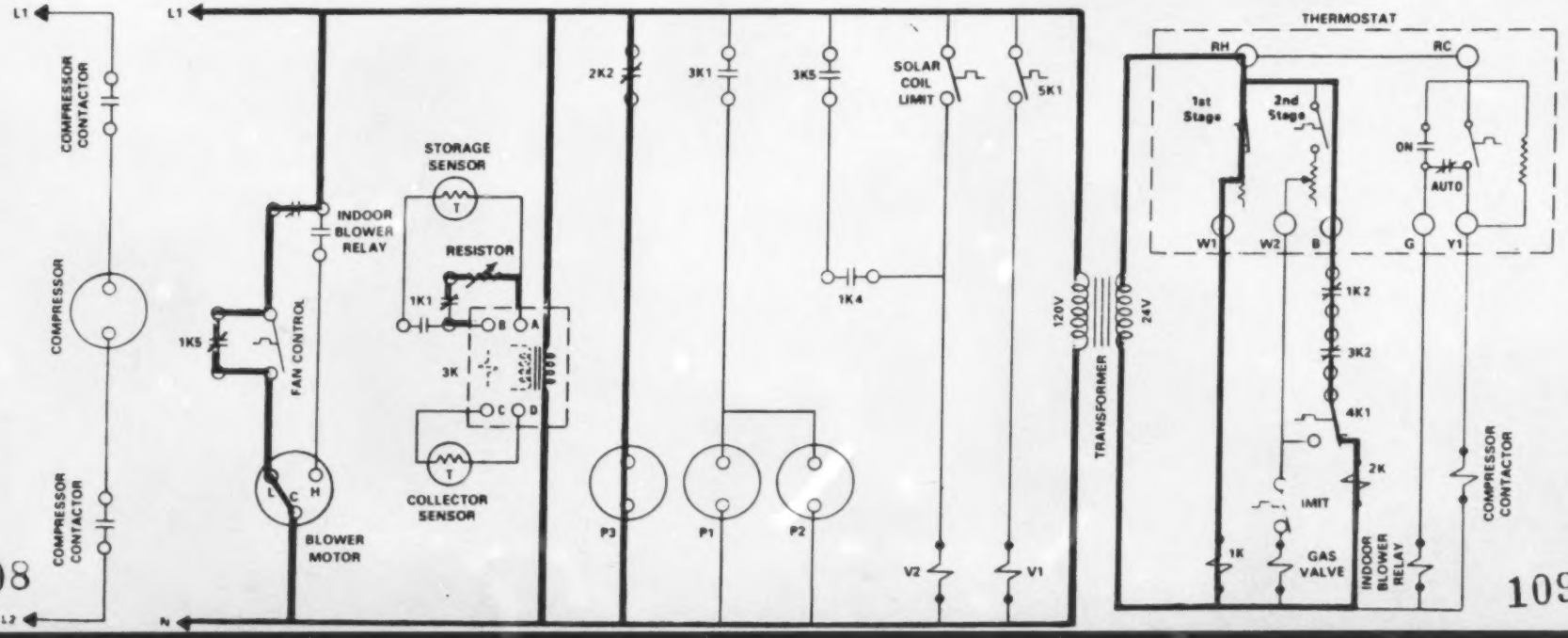




B

"Instructor's Materials"
UNIT SD-2
PROGRESS CHECK (C-1)
ORAL QUIZ





FIRST STAGE HEAT DEMAND

(No Energy Available From Collectors)
(Energy Available From Storage)

NOTE: In this mode the 4K aquastat senses storage temperature above 90° F. 4K is switched. 4K1 open and closed contacts are reversed. The circuit to 2K relay coil is not complete.

A. When the thermostat senses a demand for heat, it first closes the first stage contacts. This energizes the 1K relay coil through terminal "W1."

1. 1K5 contacts close. The circuit to the furnace blower motor is complete.

2. 1K2 contacts close. The circuit to relay 2K is complete.

3. 1K4 contacts open. The circuit to V2 valve is not complete.

4. 1K1 open and closed contacts are reversed. This bypasses the storage sensor and places a resistor in the circuit. The collector sensor now controls the 3K relay. If the collector temperature is over 110° F the 3K relay is energized. If the collector temperature is under 110° F the relay is de-energized.

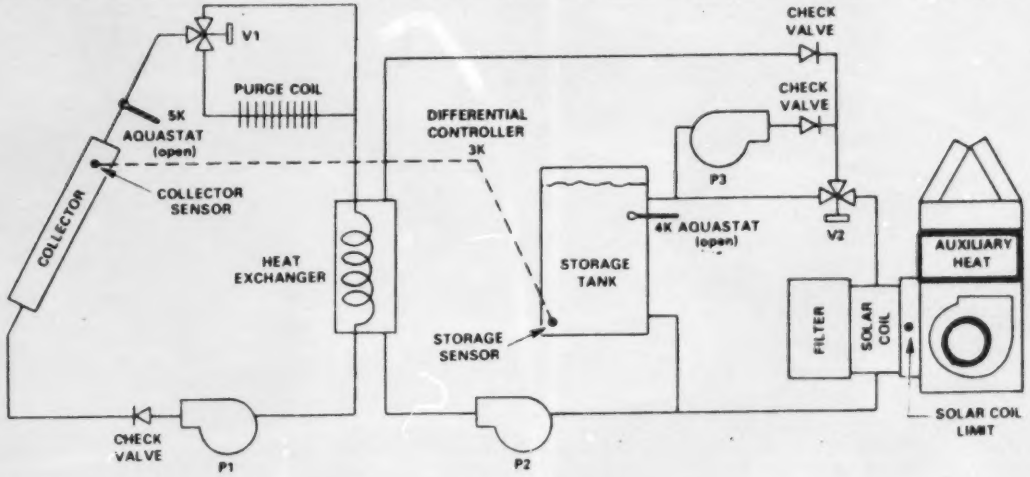
B. Since 2K relay is energized, the 2K2 contacts are closed. The circuit to pump P3 is complete.

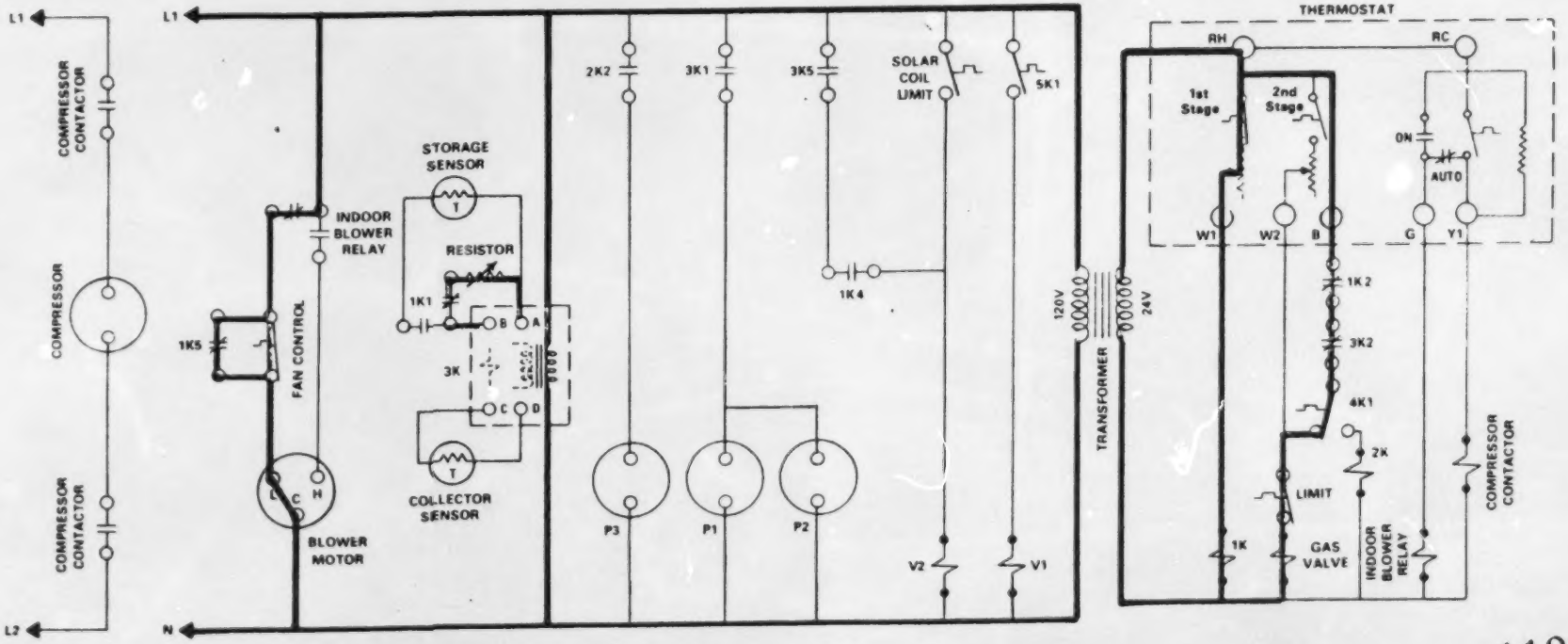
C. Since the collector temperature is under 110° F 3K relay is de-energized.

SUMMARY: Fluid is pumped from the storage tank through the de-energized valve V2 to the solar heat coil.

C

"Instructor's Materials"
UNIT SD-2
PROGRESS CHECK (C-1)
ORAL QUIZ





FIRST STAGE HEAT DEMAND

(No Energy Available From Collectors)
(No Energy Available From Storage)

A. When the thermostat senses a demand for heat, it first closes the first stage contacts. This energizes the 1K relay coil through terminal "W1."

   1. 1K5 contacts close. The circuit to the furnace blower motor is complete.

   2. 1K2 contacts close. The circuit to the gas valve is complete.

   3. 1K4 contacts open. The circuit to valve V2 is not complete.

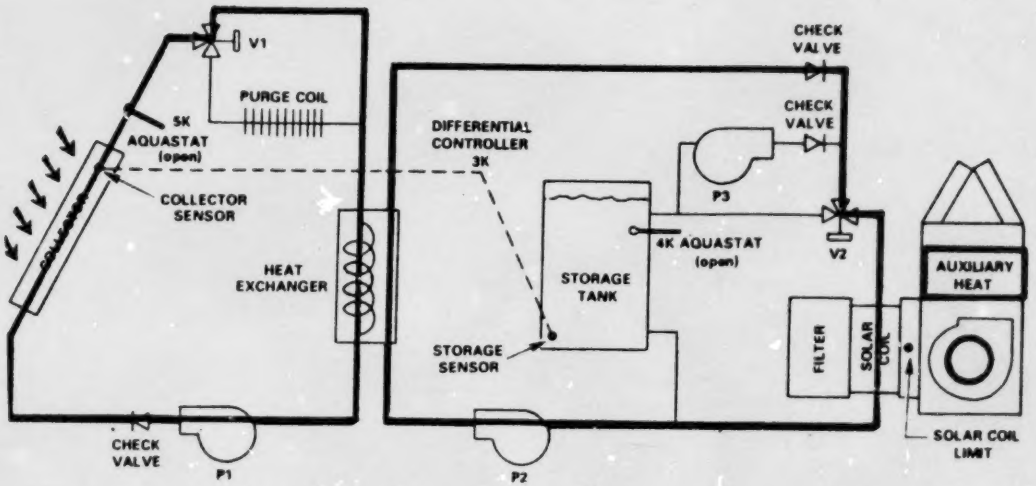
   4. 1K1 open and closed contacts are reversed. This bypasses the storage sensor and places a resistor in the circuit. The collector sensor now controls the 3K relay. If the collector temperature is over 110° F the 3K relay is energized. If the collector temperature is under 110° F the relay is de-energized.

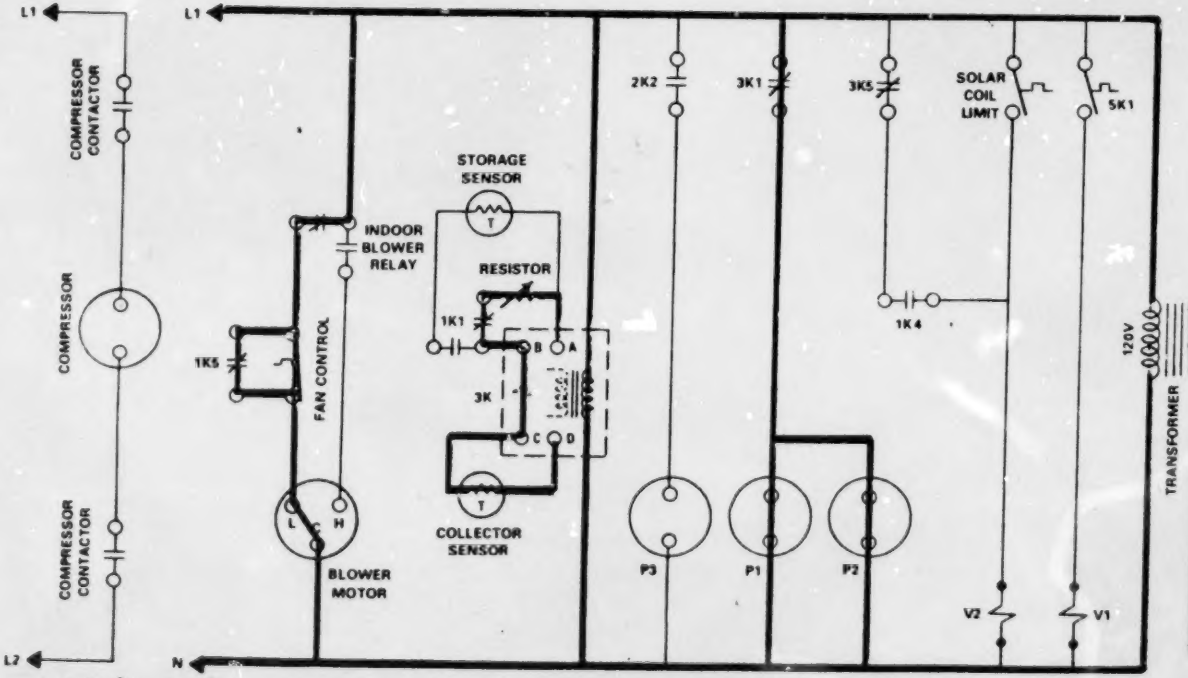
B. Since the collector temperature is under 110° F 3K relay is de-energized.

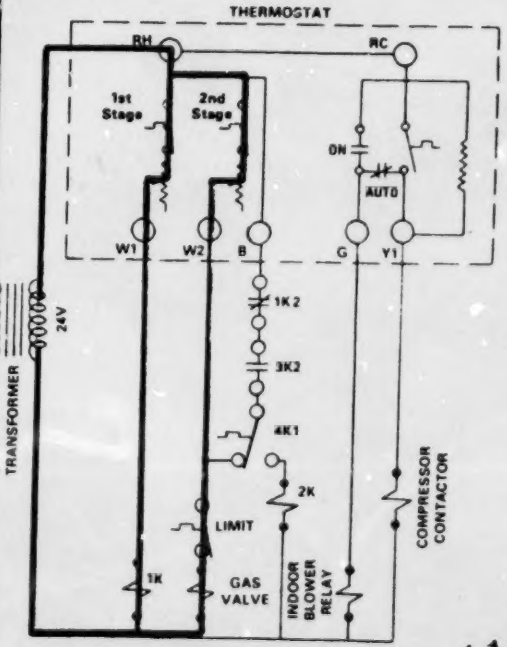
SUMMARY: In this mode the first stage of the thermostat pulled in but there was no solar heat available to satisfy the heat demand. Auxiliary heat is then operated from the first stage of the thermostat.

D

"Instructor's Materials"
UNIT SD-2
PROGRESS CHECK (C-1)
ORAL QUIZ







SECOND STAGE HEAT DEMAND

(Energy Available From Collectors)

A. The first stage contacts are already closed energized 1K relay through terminal "W1."

   1. Contacts 1K2 and 1K5 are closed. 1K4 contacts are open.

   2. 1K1 open and closed contacts are reversed.

B. Since the collector temperature is over 110° F the 3K relay is energized.

   1. 3K5 contacts are closed. The circuit to V2 valve is not complete.

   2. 3K1 contacts are closed. The circuit is complete to pumps P1 and P2.

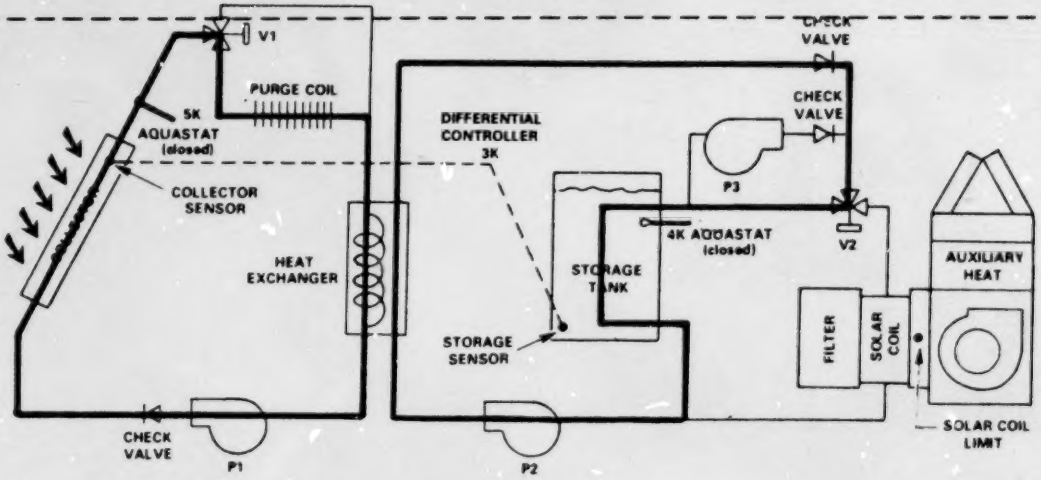
   3. 3K2 contacts are open. The circuit to the gas valve is not complete.

C. The second stage of the thermostat heating contacts close. The circuit to the gas valve is complete.

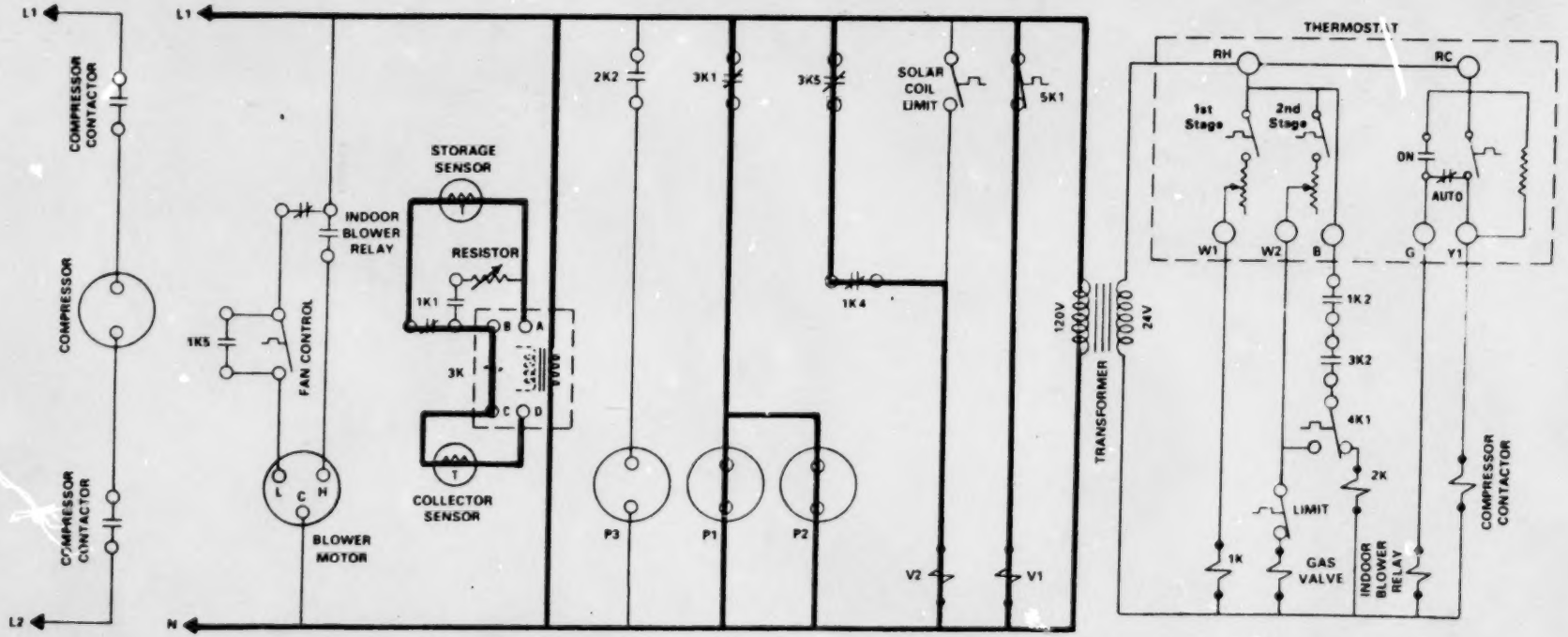
SUMMARY: The system is operating on first stage heat demand. Energy is being supplied by collectors. Solar heating cannot handle heating load so second stage pulls in auxiliary heat.

E

"Instructor's Materials"
UNIT SD-2
PROGRESS CHECK (C-1)
ORAL QUIZ



F



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PURGE CYCLE

A. There is no heat demand from the thermostat.

B. The 3K differential control senses that the collector temperature is at least 18° F higher than the storage tank temperature and is energized.

1. 3K5 contacts close. The circuit to valve V2 is complete.

2. 3K1 contacts close. Circuit to P1 and P2 pumps is complete.

3. 3K2 contacts open. Circuit to gas valve is not complete.

NOTE: The system has been taking heat from the collector and putting it into storage. As the storage gets warmer there is less heat transfer through the heat exchanger. As this occurs heat begins to build up in the collector fluid.

C. 5K aquastat senses collector fluid temperatures above 200° F. This causes 5K1 contacts to close. The circuit to V1 valve is complete.

SUMMARY: Pump P1 circulates fluid through the collector piping loop and the purge coil. Pump P2 circulates fluid through the heat exchanger to the storage tank.

UNIT SD-2
PROGRESS CHECK (C-2)
OBSERVATION & ORAL QUIZ

The Instructor will observe the student's progress through each trouble-shooting situation on Job Sheet SD-2-2.

If the student cannot find a particular problem, the Instructor may have to change the conditions (e.g., hot collector to cold collector). This could represent the serviceman coming back on another day when conditions are different.

The number of problems to be solved by each student can be varied by the Instructor, but all students should solve a minimum of ten faults.

Instructor materials are contained in the ST-17 Solar Heat Service Trainer Instructor Manual.

1. You have just finished installation and start-up of a liquid solar space heating system. Everything is working properly. You want to instruct the homeowner on what s/he can do to prevent or minimize the requirement for major service calls. List at least three things you might tell the customer.

2. A homeowner has called with a complaint that his system is costing more to operate and he is not getting heating directly from the collector on sunny days. What is the recommended four-step approach to determine the trouble?

   1.

   2.

   3.

   4.

3. You are checking out the customer complaint in Question 2 above. It is a clear, sunny day with outside temperature of 50° F. You use your multimeter across terminals F-G of the solar control panel and obtain a resistance of 3300 ohms. What two possible problems does this suggest to you?

   1.

   2.

4. A customer calls and tells you that he is not getting any air through the ducts on his heating system with either solar or auxiliary heat. You check the blower motor and find it is burned out. You also notice that someone has put a much larger U-belt pulley on the motor shaft than was originally installed. Explain to your customer the reason the blower motor failed.

5. A customer complains that he is not getting any heat from his system, but he has noticed that hot air always seems to be coming off the purge coil. You check the solar aquastat operation by adjusting the tankstat and high limit controller, but you do not hear any relays operate. Before checking further, what components might you suspect at this point to be faulty?

6. Later you find that the high limit controller, all relays, and both the aquastat and tankstat are working properly, but all working fluid is still being diverted through the purge coil. What is the problem?

7. If specific symptoms are not known in advance, what is the first step in trouble-shooting proper operation of the solar control panel?

8. After you have found the specific faulty components and fixed or replaced them, what should you do as a final step before completing your work?